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CONNECTIVITY OF BIVALVES BETWEEN MANGROVE AND SEAGRASS ECOSYSTEMS IN KELAPA DUA ISLANDS

KONEKTIVITAS BIVALVIA ANTARA EKOSISTEM MANGROVE DAN LAMUN DI PULAU KELAPA DUA

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ABSTRACT

Kelapa Dua Island, part of the Seribu Islands, is rich in biodiversity within the mangrove and seagrass ecosystems. Bivalves serve as bioindicators, crucial for assessing the health of these ecosystems. This study aimed to analyze differences in bivalve diversity between mangrove and seagrass environments and examine their associations between and within these habitats. Data were collected through mangrove and seagrass density surveys, water quality measurements, and sediment analysis. Line transect and plot methods were used for mangrove observation, while the Seagrass Watch method was applied for seagrass observation. Bivalve samples were collected using PVC pipes (up to a depth of 10 cm) for subsurface individuals and visual surveys for exposed species. The island's sandy substrate supported a variety of bivalve species. Fifteen bivalve species from six families were identified: Tellinidae, Cardiidae, Veneridae, Lucinidae, Donacidae, and Pinnidae. Bivalve density was significantly higher in the seagrass ecosystem (1,029 ind./100 m²) compared to the mangrove ecosystem (366 ind./100 m²), with the family Tellinidae showing the highest density (664 ind./100 m²). Ecological indices indicated stable conditions, with a diverse and evenly distributed bivalve community, reflecting a healthy environment. Correspondence analysis revealed that bivalve species were more concentrated in stations representing seagrass ecosystems, highlighting a stronger association with seagrass habitats.

Keywords: bivalve, coastal management, diversity, mangrove, seagrass

ABSTRAK

Pulau Kelapa Dua, bagian dari Kepulauan Seribu, kaya akan keanekaragaman hayati dalam ekosistem mangrove dan lamun. Bivalvia berfungsi sebagai bioindikator yang penting untuk menilai kesehatan ekosistem ini. Penelitian ini bertujuan untuk menganalisis perbedaan keanekaragaman bivalvia antara lingkungan mangrove dan lamun dan mempelajari hubungan bivalvia pada kedua habitat ini. Data dikumpulkan melalui survei kepadatan mangrove dan lamun, pengukuran kualitas air, dan analisis sedimen. Metode transek garis dan plot digunakan untuk pengamatan mangrove, sedangkan metode Seagrass Watch diterapkan untuk pengamatan lamun. Sampel bivalvia dikumpulkan menggunakan pipa PVC (hingga kedalaman 10 cm) untuk individu di bawah permukaan dan survei visual untuk spesies yang terlihat di permukaan. Substrat berpasir di pulau ini mendukung berbagai spesies bivalvia. Sebanyak lima belas spesies bivalvia dari enam famili teridentifikasi: Tellinidae, Cardiidae, Veneridae, Lucinidae, Donacidae, dan Pinnidae. Kepadatan bivalvia secara signifikan lebih tinggi di ekosistem lamun (1.029 ind./100 m²) dibandingkan dengan ekosistem mangrove (366 ind./100 m²), dengan famili Tellinidae menunjukkan kepadatan tertinggi (664 ind./100 m²). Indeks ekologi menunjukkan kondisi yang stabil, dengan komunitas bivalvia yang beragam dan tersebar merata, mencerminkan lingkungan yang sehat. Analisis korespondensi mengungkapkan bahwa spesies bivalvia lebih terkonsentrasi di stasiun yang merepresentasikan ekosistem lamun, menegaskan hubungan yang lebih erat dengan habitat lamun.

Kata kunci: bivalvia, coastal manajemen, diversitas, lamun, mangrove

INTRODUCTION

Kelapa Dua Island, in Seribu Islands National Park, is a rich ecosystem of mangroves and seagrasses, which makes it an important site for the study of bivalve diversity. These coastal ecosystems support high biodiversity and play an important role in maintaining ecological balance, particularly as a buffer between the coastal zone and the marine environment. Bivalves play an important role in water purification and the management of natural resources (Voight 2015; Rogers and Kimbro 2015).

Seagrass meadows provide important habitats for marine organisms, including fish, crustaceans, and mollusks (Tan *et al.* 2020). Additionally, seagrass meadows help stabilize sediments, improve water quality, and absorb atmospheric carbon dioxide from the atmosphere (Saderne *et al.* 2019). Each region in Indonesia has different types of seagrasses due to differences in environmental conditions or anthropogenic pressure, so it is necessary to study the types of seagrass in Indonesian waters. Mangrove and seagrass ecosystems play crucial roles in supporting bivalve life. Both ecosystems provide habitat, nutritional sources, and breeding grounds for various marine organisms and also serve to protect coastlines from erosion, sequester carbon, and enhance water quality through natural filtration processes (James *et al.* 2019; Infantes *et al.* 2022; Nugraha *et al.* 2019). Despite extensive research, the biodiversity of bivalves within these ecosystems is not fully understood, particularly in regions such as Seribu Islands, Indonesia.

Bivalves, a group of mollusks that includes more than 30,000 species (Furkon *et al.* 2020). They filter food particles from the water, functioning as filter feeders, a process that enhances water quality (Karimah 2017) and supports nutrient cycling through the release of nutrient-rich waste (Lønborg *et al.* 2021). Bivalves also serve as food sources for various predators, such as fish, birds, and mammals (Ermgassen *et al.* 2021), and act as bio-indicators for assessing water quality (Suminar *et al.* 2020). Their ability to filter food is closely linked to their potential to absorb pollutants such as heavy metals, which can impact ecosystem health (Chahouri *et al.* 2023). Understanding the distribution and diversity of bivalves is crucial for monitoring the coastal ecosystem's health.

This study aims to analyze differences in bivalve diversity between mangrove and seagrass environments and examine their associations between and within these habitats on the coast of Kelapa Dua Island, Seribu Islands, Jakarta. The findings of this study are expected to support conservation efforts for mangrove and seagrass ecosystems and contribute to the monitoring of coastal ecosystem health in the area.

METHODS

Time and location

This survey was carried out on Kelapa Dua Island, Seribu Islands, in March 2023, by selecting three stations representing mangrove and seagrass ecosystems. Stations 1M and 2M represent the mangrove ecosystem, and Stations 2L and 3L represent the seagrass ecosystem. The choice of stations is based on differences in ecosystem characteristics to provide a complete picture of bivalve distribution. The location of the study area is illustrated in Figure 1, which includes a geographical map and the location of the stations.

Data collection

Physical-chemical parameters of water

Physicochemical water parameters, such as temperature, salinity, pH, and dissolved oxygen (DO) levels, were measured directly in the field at each research station using pre-calibrated portable instruments. The instruments used in this study included a thermometer, pH meter, refractometer, and DO meter to measure the temperature, pH, salinity, and dissolved oxygen, respectively. Measurements were taken at 0.5 m depth at the water surface to obtain representative data on water conditions at each study site. The physicochemical parameters of the water (temperature, salinity, pH, and DO) were measured onsite.

Sediment sampling

Sediment samples were collected using a corer made from a 10 cm diameter PVC pipe, 15 cm long, which was inserted into the substrate to 5-10 cm in depth. Sediment sampling was conducted at each research station in triplicate. Sediment fraction analysis was performed ex-situ using dry and wet sieving methods in the laboratory, and the sediment grain sizes were determined based on the Wentworth scale (Switzer and Pile 2015).

Mangrove, seagrass, and bivalve data collection

Mangrove observations were conducted using a 50 m line transect with plots every 10 m, consisting of three plots and three repetitions. The data included the identification of species and the number of mangrove trees categorized into three groups: trees, saplings, and seedlings (Bengen 2004). Seagrass observations employed the method to measure seagrass species density (McKenzie and Yoshida 2013), using a 50 m line transect perpendicular to the shore, with a 25 m distance between transects. Each station was observed three times, with square plots (0.5 m × 0.5 m) every 5 m. Bivalve data were collected using the visual census method for those visible on the surface and a PVC pipe up to 10 cm for those present in the substrate. Observations were conducted concurrently with mangrove and seagrass data using square transects. The bivalve specimens collected from the substrate were filtered to remove sediment, cleaned, stored in labeled plastic bags, preserved in 70% alcohol, and kept in a cool box for further identification in the laboratory. Identification was performed at the Marine Bioprospecting and Biomaterials Laboratory, FPIK, IPB University, according to FAO (1998).

Data analysis

Density of mangrove and seagrass species

Type density is defined as the number of individuals of a species within a given range. The type density calculation used the following formula from English *et al.* (1997):

$$Di = \frac{Ni}{A}$$

Description:
Di = Density of species i (ind/m^2)
Ni = Total number of individuals of species i (ind)
A = Total sampling area (m^2)

The seagrass density levels are classified based on Braun-Blanquet (1965) as: very dense, dense, moderately dense, sparse, and very sparse, with corresponding seagrass density values of: >175, 125-175, 75-125, 25-75, and <25 (ind./m^2), respectively.

Bivalve density

The bivalve density was calculated using the following formula from Brower *et al.* (1990):

$$Di = \frac{Ni}{A} \times 100\%$$

Description:
Di = Density of species i (ind/m^2)
Ni = Total number of individuals of species i (ind)
A = Total sampling area (m^2)

Bivalve diversity index (H')

Bivalve diversity was calculated using the Shannon–Weiner index in Bengen (2000):

$$H' = -\sum_{i=1}^{n} Pi \log_2 Pi$$

Description:
H′ = Shannon-Wiener diversity index
Pi = Proportion of individuals of species i relative to the total number of individuals (*Ni/N*)
Ni = Number of individuals of species i obtained
N = Total number of individuals

The categories of diversity index values based on Magurran (2004) were as follows: $H'<1$, low-type diversity; $1\leq H'\leq 3$, medium-type diversity; and $H'>3$, high-type diversity.

Evenness index (E)

The evenness index was calculated using the formula of Magurran (2004):

$$E = \frac{H'}{log2\, S}$$

Description:
E = Evenness index
S = Number of species

The categories of the evenness index value according to Junita *et al.* (2020) are as follows: $E<0.4$: low species evenness, $0.6\geq E \geq 0.4$: moderate species evenness, and $E>0.6$: high species evenness.

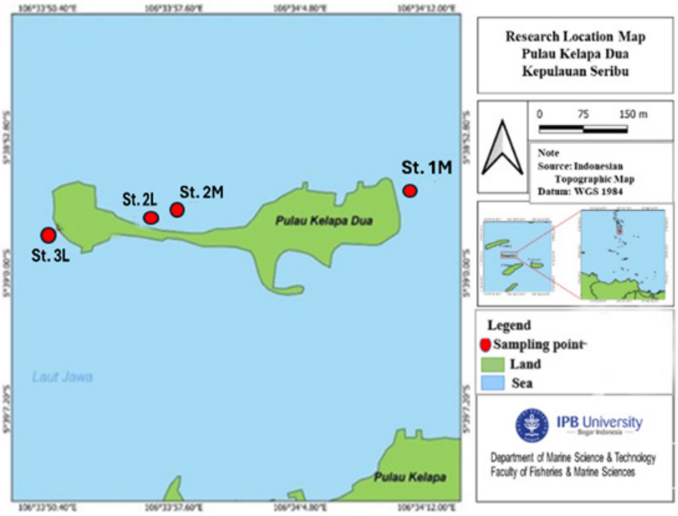

Figure 1. Map of the research location on the coast of Kelapa Dua Island, Seribu Islands.

Dominance index (C)

The dominance index used the Simpson formula (Magurran 2004):

$$C = \sum_{i=1}^{n} \left(\frac{Ni}{N}\right)^2 = \sum pi^2$$

Description:
C = Dominance index
The criteria for the dominance index values are as follows: 0<C≤0.5: low dominance, 0.5< C≤0.75: moderate dominance, and 0.75<C≤1: high dominance (Junita *et al.* 2020).

Spatial distribution of bivalves with mangroves and seagrass

The spatial distribution and association of bivalves with mangrove and seagrass ecosystems were analyzed using correspondence analysis (CA) (Bengen 2000) with the assistance of XL-Stat 2023 software on Microsoft Excel. The CA method is a factorial analysis that groups statistical units into homogeneous clusters based on a set of variables or characteristics (Bengen 2000). The variables tested in the correspondence analysis included bivalve species related to the density of mangroves and seagrass.

RESULTS AND DISCUSSION

Characteristics of the aquatic environment

Physicochemical factors of water, such as temperature, salinity, pH, and dissolved oxygen (DO) levels, play crucial roles in determining the survival of marine organisms, including bivalves. Small changes in these parameters, such as increases in temperature or pH fluctuations, can affect the metabolism, reproduction, and distribution of bivalves. Higher temperatures can accelerate growth; however, extreme temperatures can cause stress, thereby affecting the metabolism and resilience of organisms (Natsir and Allifah 2020). The results of water quality measurements at the research site are presented in Table 1.

Table 1. Results of measuring environmental parameters of coastal waters of Kelapa Dua Island, Seribu Islands.

Stations	Location	Temperature (°C)	Salinity (ppt)	pH	DO (mg/l)
1M	Mangrove area	29.3	31	8	5.9
2M-2L	Mangrove and seagrass areas	28.5	30	8.5	6.4
3L	Seagrass area	29.2	31	8.6	6.7
Seawater quality standards for bivalves		28-32[a]	5-35[b]	6.5-8.5[c]	>5[c]

Sources: [a]Zahroh *et al.* (2019); [b]Widasari *et al.* (2013); [c]Effendi (2003)

The temperature across all observation stations ranged from 28.5°C to 29.3°C, which remains within the optimal range for bivalve life, as stated by Zahroh *et al.* (2019). This temperature supports metabolic activity, accelerates growth, and improves food filtration efficiency. An increase in temperature can lead to a decrease in dissolved oxygen levels as the solubility of gases diminishes at higher temperatures (Breitburg *et al.* 2018). This condition not only reduces the quality of bivalve habitats but also has the potential to disrupt the overall ecosystem structure, including other organisms that depend on water conditions (Islami 2013). Dissolved oxygen is crucial for biological and biogeochemical processes in the ocean, and its reduction can affect marine productivity, biodiversity, and biogeochemical cycles (Breitburg *et al.* 2018).

The salinity at the study site ranged from 30 to 31 ppt, with consistent variation across all stations. This salinity range supports the survival of bivalves as these organisms have limited tolerance to salinity changes. Extreme fluctuations, such as those caused by heavy rainfall or tidal shifts, can induce osmotic stress, which disrupts growth, reproduction, and survival in bivalves (Widasari *et al.* 2013; Islami 2013; Abe *et al.* 2024). Research conducted by Cao *et al.* (2022) indicates that high salinity has detrimental effects on bivalve species, such as *Sinonovacula constricta*, particularly on survival, gill structure, enzyme activity, and amino acid content.

The pH values across all stations ranged from 8.0 to 8.6, which fell within the acceptable range for bivalves (7.5-8.5), supporting important biochemical processes for their growth and reproduction. Suwondo *et al.* (2012) stated that a pH range of 6-9 can still support bivalve life. Extreme pH fluctuations can disrupt bivalve survival, particularly during the larval stage (Effendi 2003).

The results of the dissolved oxygen (DO) measurements at the observation site showed values ranging from 5.9 mg/l to 6.7 mg/l, which align with the quality standard set by Effendi (2003), indicating that the dissolved oxygen levels are suitable for aquatic organisms. Based on the measurement results, it can be concluded that the water conditions at Kelapa Dua Island support the life of bivalves. Stable temperatures and appropriate salinity levels support metabolism and growth. Good water quality also promotes bivalve survival in this area. However, changes in environmental factors owing to climate change or human activities can affect the distribution and composition of bivalve species. Therefore, continuous monitoring of the physicochemical parameters of water is essential for the conservation of this ecosystem.

The measurement results indicate that the water conditions in Pulau Kelapa Dua support the life of bivalves, with stable temperatures and suitable salinity levels for their metabolism and growth. Good water quality also contributes as a supporting factor for the survival of bivalves in this area. The distribution and composition of bivalve species can be influenced by environmental factor changes caused by climate change or human activities, although the current water conditions still support their survival. Continuous monitoring of physicochemical water parameters is an important step to preserve this ecosystem.

Characteristics of the substrate

Substrate analysis in the waters of Kelapa Dua Island shows the dominance of sand (90.49%-96.03%), followed by gravel (3.29%-8.62%), silt (0.49%-1.03%), and clay (0.40%-0.57%), as shown in Figure 2. Sandy substrates support the distribution of bivalves, as they allow for good water penetration, space for burrowing, and efficient particle filtration for food (Akhrianti *et al.* 2014). Fine sand with organic material content also enhances food availability, thereby supporting growth and reproduction. Substrate conditions also influence the diversity, evenness, and dominance of bivalve distribution (Afriyansyah *et al.* 2023).

Sandy substrates generally host few organisms because of their coarse particles and limited shelter (Brady and Weil 2016); however, the presence of mangroves and seagrass in the study area enhances biodiversity. Vegetation provides protection and adds organic matter to the sediment, which is crucial for the survival of bivalves (Dąbrowska *et al.* 2016). According to Akhrianti *et al.* (2014), bivalves tend to prefer sandy substrates because they support a burrowing lifestyle and filter organic particles through their siphons. In Kelapa Dua Island, the combination of sandy substrate and vegetation creates ideal conditions for the abundance and distribution of bivalves.

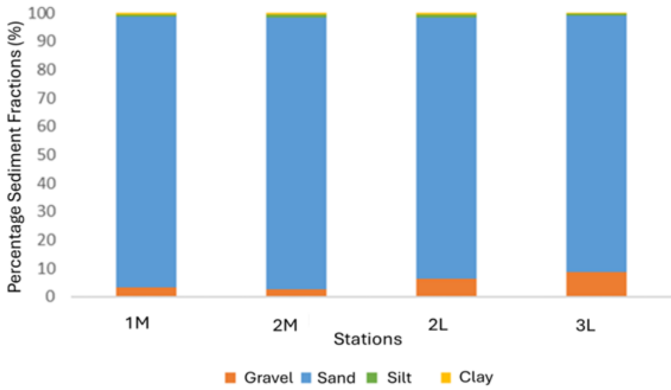

Figure 2. Percentage of sediment fraction on the coast of Kelapa Dua Island, Seribu Islands.

Mangrove density on the coast of Kelapa Dua Island

In the coastal waters of Kelapa Dua Island, only one species of mangrove, *Rhizophora stylosa*, was found. *R. stylosa* is a mangrove species that is characterized by unique ecological adaptations. The mangroves found in the Kelapa Dua Island area were the result of rehabilitation using the clustered planting method. This species thrives in saline environments and shows significant growth responses to various salinity and temperature (Inoue *et al.* 2024). Mangrove density is highly influenced by various environmental factors, including water quality, substrate type, pH, temperature, and nutrient availability in the environment (Rinaldi *et al.* 2021; Wang *et al.* 2024). The substrate conditions at both stations were similar, with sand dominance and physicochemical parameters. According to Jalaludin *et al.* (2020), *R. stylosa* is not only capable of growing and thriving in high-salinity waters but also prefers habitats along island shores with sandy substrates or coral fragments. This makes it highly suitable for planting in the Seribu Islands National Park, including on Kelapa Dua Island.

Mangrove density varied across study sites (Table 2). At Station 1M (natural mangrove area), the density recorded was 2 ind./100m^2, whereas at Station 2M (closer to the rehabilitation zone), the density was higher, reaching 30 ind./100m^2. This difference indicates that environmental conditions, such as proximity to human activities or rehabilitation efforts, can influence the number of mangrove individuals growing in a given location. Station 1M was dominated by juvenile mangroves and seedlings, indicating that the trees were still in the early stages of growth.

Seagrass density on the coast of Kelapa Dua Island

Ikhsan *et al.* (2019) stated that each region in Indonesia has different types of seagrass due to differences in environmental conditions or anthropogenic pressures. The Seagrass vegetation along the coast of Kelapa Dua Island consists of several species, including *Thalassia hemprichii*, *Cymodocea rotundata*, *Halophila ovalis*, and *Syringodium isoetifolium*. The density of each species is shown in Figure 3. *C. rotundata* was dominant with the highest density, reaching 170 ind./m^2 at Station 2L and 148 ind./m^2 at Station 3L. *C. rotundata*, as a pioneer species, can adapt well to environmental fluctuations, maintain substrate stability, and provide habitat for other species (Kawaroe *et al.* 2016).

The density of *H. ovalis* varied between stations: 68 ind/m^2 classified as sparse according to Braun-Blanquet (1965) at Station 2L and 114 ind./m^2 (classified as moderately dense) at Station 3L. *T. hemprichii* was infrequently observed at both stations, with a density of 38 ind/m^2 at Station 2L and 37 ind./m^2 at Station 3L. *S. isoetifolium* was only found at St 2L, where it had a density of 8 ind./m^2, classifying it as very rare (<25 ind./m^2) (Braun-Blanquet 1965). *S. isoetifolium* has low tolerance to drought and is more commonly found in areas that are always submerged in water.

Distribution and density values of bivalve families

Six bivalve families were found along the coast of Kelapa Dua Island: Tellinidae and Cardiidae (4 species each), Veneridae (3 species), Lucinidae (2 species), Donacidae and Pinnidae (1 species each). The families

Tellinidae, Cardiidae, Veneridae, and Lucinidae were found in both the mangrove and seagrass ecosystems, demonstrating good adaptation to various environmental conditions. The highest densities of these four families were recorded in the seagrass ecosystem (Stations 2L and 3L), indicating that seagrass strongly supports the presence of bivalves. This finding was supported by Fales *et al.* (2020), who showed that seagrass plays a role in enhancing the survival of bivalves. According to Sanmartí *et al.* (2018), the biological activities of bivalves, such as particle filtration, play an important role in improving seagrass health by enhancing water clarity and light intensity for photosynthesis. Families such as Tellinidae and Veneridae include fast-burrowing species that contribute to improving water circulation and increasing oxygen levels in the substrate, thereby supporting the growth of other organisms. García-Souto *et al.* (2017) stated that Tellinidae is highly adaptable to sandy substrates, the dominant substrate in the coastal waters of Kelapa Dua Island. Tellinidae is the largest family in Kelapa Dua Island, making a significant contribution to improving water circulation, increasing oxygen levels, and supporting ecosystem health. The distribution of family densities is shown in Figure 4.

Table 2. Density of mangrove species *R. stylosa* on the coast of Kelapa Dua Island.

Stations	Mangrove Species Density (ind/100 m^2)
1M	2
2M	30

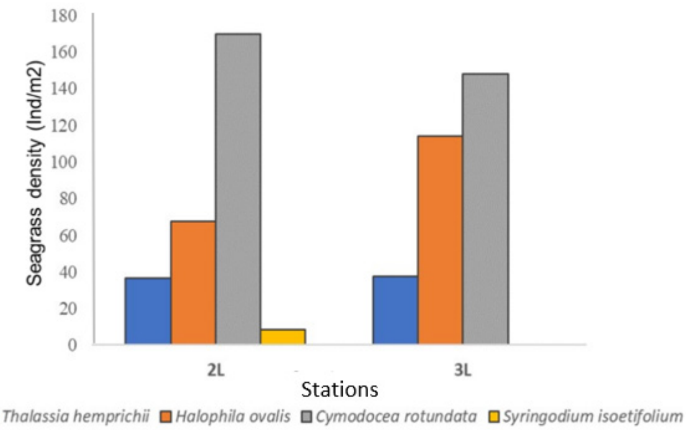

Figure 3. Seagrass density on the coast of Kelapa Dua Island.

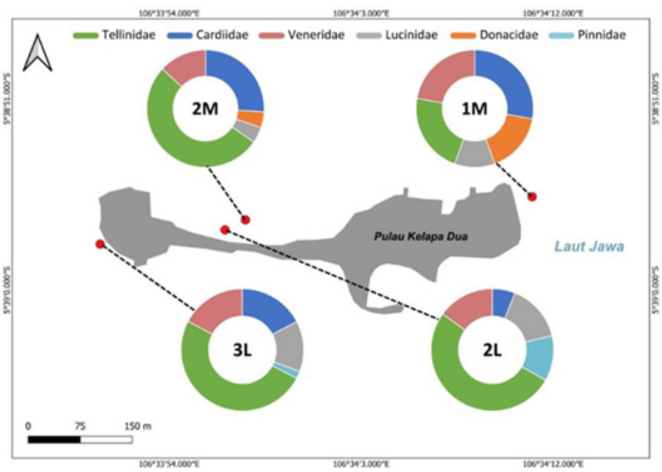

Figure 4. Distribution of bivalve family density on the coast of Kelapa Dua Island.

According to Thalia *et al.* (2021), the families Tellinidae, Cardiidae, Veneridae, and Lucinidae are common bivalve groups that are frequently encountered, particularly in Southeast Asian countries. The density values for each family at each station are presented in Table 3. The bivalve community structure in the mangrove and seagrass ecosystems was similar, with the Tellinidae family dominating, with density values ranging from 107 to 315 ind./100 m^2, except at Station 1M, which showed a more even distribution of families.

The distribution of bivalve families in the mangrove ecosystem at Stations 1M and 2M was similar, with 5 out of 6 families present, although the percentage of each family differed. The family Pinnidae was found only in the seagrass ecosystem (Stations 2 L and 3 L), with a total density of 60 ind/100 m^2. Pinnidae has a large morphology with a triangular-shaped shell and a pointed end, living in sandy substrates, and associating with seagrass (Susetya *et al.* 2022). Donacidae, which typically inhabits sandy shores and moves with tides, was only found in mangroves (Stations 1M and 2M), with the lowest density of 36 ind/100 m^2 (El-Ghobashy *et al.* 2011).

This distribution reflects the specific adaptations of each family to different environmental conditions in the mangrove and seagrass ecosystems. The Donacidae family tends to inhabit sandy beach habitats, live in groups, and exhibit movement patterns influenced by tides (El-Ghobashy *et al.* 2011). This distribution illustrates the specific adaptations of each family to various environmental conditions in the mangrove and seagrass ecosystems.

Distribution and density value of bivalve species in Kelapa Dua Island

The bivalve species found along the coast of Kelapa Dua Island included *Fimbria fimbriata*, *Fragum fragum*, *Fragum unedo*, *Gafrarium pectinatum*, *Latona deltoides*, *Loripes orbiculatus*, *Maoricardium pseudolatum*, *Periglypta puerpera*, *Pinna muricata*, *Quidnipagus palatam*, *Tellinela virgata*, *Tellinides timorensis*, *Vasticardium pectineforme*, *Timoclea marica*, and *Quadrans gargadia*. The species density of the bivalve are presented in Table 4 and their distributions are shown in Figure 5.

Bivalve ecological index on the coast of Kelapa Dua Island

The bivalve ecological indices, including the Shannon–Wiener diversity index (H'), evenness index (E), and dominance index (C), are presented in Table 5. The diversity index values for bivalve species show variations that reflect differences in species richness and the distribution of individual numbers or bivalve species, even within the same habitat, such as seagrass or mangroves. The diversity index at Station 2L was classified as high with an H' value greater than 3, whereas the other stations fall within the moderate category (Magurran 2004). This indicates that the bivalve population is in a stable condition, with a fairly diverse range of species and a relatively large number of individuals.

Based on the criteria of Junita *et al.* (2020), the evenness index of the bivalve community at the study sites fell into the high category (E>0.6), indicating a balanced distribution of individuals among species. This reflects a stable ecosystem with an optimal environment that supports the sustainability of all species.

Simpson's dominance index (C) was categorized as low according to Junita *et al.* (2020), indicating the absence of species dominance within the bivalve community. The low dominance index reflects the health of the seagrass and mangrove ecosystems in Kelapa Dua Island, supported by optimal environmental conditions that facilitate species diversity and balanced interspecies interactions. This allows the ecological functions of bivalves, such as water filtration and nutrient cycling (Beck *et al.* 2011), to operate efficiently.

Spatial distribution of bivalves in mangrove and seagrass ecosystems on Kelapa Dua Island

The results of the correspondence analysis (CA) shows that the distribution of bivalve species at the study stations, which characterize the mangrove and seagrass ecosystems, was concentrated along axis 1 (F1) with a contribution of 48.2% and axis 2 (F2) with 39.74%, explaining a total of 87.93% of the variance. The spatial distribution of the bivalve species in these ecosystems is shown in Figure 6.

Table 3. The density value of bivalve families on the coast of Kelapa Dua Island.

No	Families	Bivalve Density (ind./100m²)			
		St. 1M	**St. 2M**	**St. 2L**	**St. 3L**
1	Tellinidae	36	107	206	315
2	Cardiidae	44	53	24	109
3	Veneridae	36	27	60	109
4	Lucinidae	18	9	61	85
5	Donacidae	27	9	-	-
6	Pinnidae	-	-	48	12
	Total	**161**	**205**	**399**	**630**

Table 4. Bivalve species density value on the coast of Kelapa Dua Island.

No	Species	Density (ind./100m²)			
		1M	**2M**	**2L**	**3L**
1	*Fimbria fimbriata*	18	9	0	0
2	*Fragum fragum*	0	0	0	24
3	*Fragum unedo*	0	0	0	24
4	*Gafrarium pectinatum*	0	44	24	0
5	*Latona deltoides*	27	9	0	0
6	*Loripes orbiculatus*	0	0	61	85
7	*Maoricardium pseudolatum*	0	18	24	0
8	*Periglypta puerpera*	0	0	0	24
9	*Pinna murikata*	0	0	48	12
10	*Quidnipagus palatam*	0	62	36	0
11	*Tellinella virgata*	0	27	48	61
12	*Tellinides timorensis*	0	0	61	73
13	*Timoclea marica*	36	0	36	85
14	*Vasticardium pectiniforme*	44	0	0	61
15	*Quadrans gargadia*	36	18	61	182
	Total Density	**160**	**187**	**400**	**631**

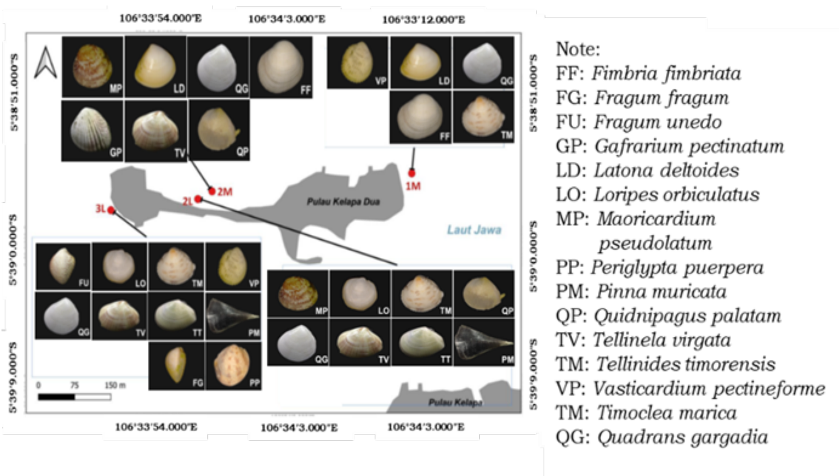

Figure 5. Distribution of bivalve species on the coast of Kelapa Dua Island.

Table 5. Bivalve ecological index value on the coast of Kelapa Dua Island.

Ecological Index	Stations			
	1M	2M	2L	3L
Diversity Index (H')	2.26	2.49	3.09	2.96
Evenness Index (E)	0.97	0.89	0.98	0.89
Dominance Index (C)	0.03	0.11	0.02	0.11

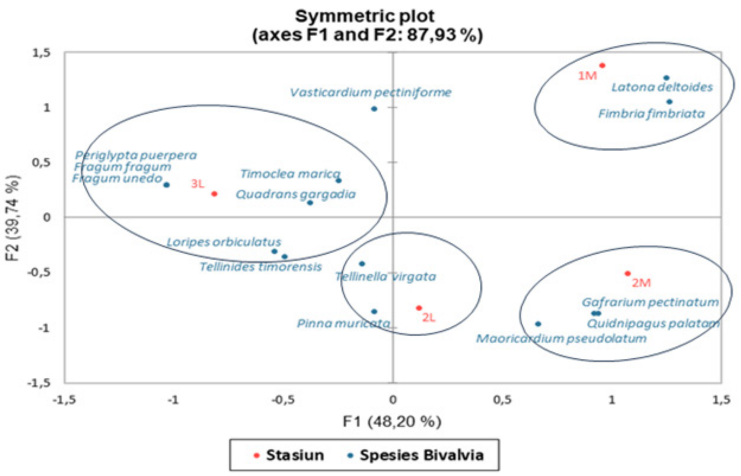

Figure 6. CA results of bivalve species on mangrove ecosystems (Stations 1M, 2M) and seagrass (Stations 2L, 3L) on Kelapa Dua Island.

The CA results identified two groups of bivalve species distributions that characterize mangrove and seagrass ecosystems. Species associated with mangroves included *L. deltoides*, *F. fimbriata*, *G. pectinatum*, *Q. palatum*, and *M. pseudolatum*, whereas species associated with seagrass included *T. virgata*, *P. muricata*, *T. marica*, *Q. gargadia*, *F. fragum*, *F. unedo*, *P. puerpera*, *L. orbiculatus*, and *T. timorensis*. The high number of bivalve species at Station 3L is due to favorable substrate conditions and the high density of seagrass species *T. hemprichii* and *C. rotundata*.

CONCLUSION

This study identified 15 bivalve species along the coast of Kelapa Dua Island, Seribu Islands from six families: Tellinidae and Cardiidae (four species each), Veneridae (three species), Lucinidae (two species), Donacidae and Pinnidae (one species each). The density of the bivalves was higher in the seagrass ecosystem than in the mangrove ecosystem. Correspondence analysis demonstrated that bivalve distribution patterns exhibit a closer ecological linkage to seagrass habitats. Species associated with seagrass included *T. virgata*, *P. muricata*, *T. marica*, *Q. gargadia*, *F. fragum*, *F. unedo*, *P. puerpera*, *L. orbiculatus*, and *T. timorensis*, whereas those associated with mangroves included *L. deltoides*, *F. fimbriata*, *G. pectinatum*, *Q. palatum*, and *M. pseudolatum*. The ecological indices indicated that the bivalve community was stable, with relatively high diversity and no species dominance, reflecting a well-balanced ecological condition.

REFERENCES

Abe H, Namba M, Ito MA, Nakaoka M. 2024. Effects of Low Salinity Water Inflow on Eelgrass and Cultured Bivalves in Subarctic Lagoons: Analysis Using Hydrodynamic Model. *Regional Studies in Marine Science*. 74: 103543. DOI: https://doi.org/10.1016/j.rsma.2024.103543.

Afriyansyah B, Insyira R, Papingka T, Islamiyah U, Syazili A, Lissoliha, Edelweis MA, Roshan RA, Meilya R, Julisa SI, Tiwi R, Fauziyah Z, Rangga MY, Septiani H, Pratoyo GH, Winanto, Lingga R, Henri. 2023. Studi Perbandingan Keanekaragaman

Bivalvia dan Gastropoda pada Pulau-Pulau Kecil di Bangka. *Jurnal Ruaya: Jurnal Penelitian dan Kajian Ilmu Perikanan dan Kelautan*. 11(1): 64-73. DOI: https://doi.org/10.29406/jr.v11i1.4369.

Akhrianti I, Bengen DG, Setyobudiandi I. 2014. Spatial Distribution and Habitat Preference of Bivalvia in the Coastal Waters of Simpang Pesak Sub District, East Belitung District. *Jurnal Ilmu dan Teknologi Kelautan Tropis*. 6(1): 171-185. DOI: https://doi.org/10.29244/jitkt.v6i1.8639.

Beck MW, Brumbaugh RD, Airoldi L, Carranza A, Coen LD, Crawford C, Defeo O, Edgar GJ, Hancock B, Kay MC, Lenihan HS, Luckenbach MW, Toropova CL, Zhang G, Guo X. 2011. Oyster Reefs at Risk and Recommendations for Conservation, Restoration, and Management. *BioScience*. 61(2): 107-116. DOI: https://doi.org/10.1525/bio.2011.61.2.5.

Bengen DG. 2000. *Sinopsis Teknik Pengambilan Contoh dan Analisis Data Biofisik Sumberdaya Pesisir*. Bogor (ID): Pusat Kajian Sumberdaya Alam Pesisir dan Lautan (PKSPL) IPB.

Bengen DG. 2004. *Pedoman Teknis Pengenalan dan Pengelolaan Ekosistem Mangrove*. Bogor (ID): Pusat Kajian Sumberdaya Pesisir dan Laut (PKSPL) IPB.

Brady NC, Weil RR. 2016. *The Nature and Properties of Soils* (*15th ed.*). Columbus (US): Pearson.

Braun-Blanquet J. 1965. *Plant Sociology: The Study of Plant Communities*. London (GB): Hafner Publishing Company.

Breitburg D, Levin LA, Oschlies A, Grégoire M, Chavez FP, Conley DJ, Garçon V, Gilbert D, Gutiérrez D, Insensee K, Jacinto GS, Naqvi SWA, Pitcher GC, Rabalais NN, Roman MR, Rose KA, Seibel BA, Telszewski M, Yasuhara M, Zhang J. 2018. Declining Oxygen in the Global Ocean and Coastal Waters. *Science*. 359: 6371. DOI: https://doi.org/10.1126/science.aam7240.

Brower JE, Zar JH, von Ende CN. 1990. *Field and Laboratory Methods for General Ecology*. Dubuque (US): WCB Publishers.

Cao W, Bi S, Chi C, Dong Y, Xia S, Liu Z, Zhou L, Sun X, Geng Y, Wu B. 2022. Effects of High Salinity Stress on the Survival, Gill Tissue, Enzyme Activity and Free Amino Acid Content in Razor Clam *Sinonovacula constricta*. *Frontiers in Marine Science*. 9: 839614. DOI: https://doi.org/10.3389/fmars.2022.839614.

Chahouri A, Yacoubi B, Moukrim A, Banaoui A. 2023. Bivalve Molluscs as Bioindicators of Multiple Stressors in the Marine Environment: Recent Advances. *Continental Shelf Research*. 264: 105056. DOI: https://doi.org/10.1016/j.csr.2023.105056.

Dąbrowska AH, Janas U, Kendzierska H. 2016. Assessment of Biodiversity and Environmental Quality Using Macrozoobenthos Communities in the Seagrass Meadow (Gulf of Gdańsk, Southern Baltic). *Oceanological and Hydrobiological Studies*. 45(2): 286-294. DOI: https://doi.org/10.1515/ohs-2016-0024.

Effendi H. 2003. *Telaah Kualitas Air bagi Pengelolaan Sumber Daya dan Lingkungan Perairan*. Yogyakarta (ID): Kanisius.

El-Ghobashy AE, Mahmad SZ, Kandeel SK, El-Ghitany AH. 2011. Factors Associated with the Distribution of the Invasive Bivalve Clams "*Donax Variabilis* (Say, 1822)" at the Area of the Mediterranean Coast Preferred by Marine Fish Larvae New Damietta, Egypt. *Journal of American Science*. 7(1): 1051-1062.

English S, Wilkinson C, Baker V. 1997. *Survey Manual for Tropical Marine Resources* (*2nd Edition*). Townsville (AU): Australian Institute of Marine Science (AIMS).

Ermgassen PSE, Mukherje N, Worthington TA, Acosta A, Araujo ARR, Beitl CM, Castellanos-Galindo GA, Cunha-Lignon M, Dahdouh-Guebas F, Diele K, Parrett CL, Dwyer PG, Gair JR, Johnson AF, Kuguru B, Lobo AS, Loneragan NR, Longley-Wood K, Mendonça JT, Meynecke J-O, Mandal RN, Munga CN, Reguero BG, Rönnbäck P, Thorley J, Wolff M, Spalding M. 2021. Fishers Who Rely on Mangroves: Modelling and Mapping the Global Intensity of Mangrove-Associated Fisheries. *Estuarine, Coastal and Shelf Science*. 248: 107159. DOI: https://doi.org/10.1016/j.ecss.2020.107159.

[FAO] Food and Agriculture Organization. 1998. *The Living Marine Resources of The Western Central Pacific, Vol 1: Seaweeds, Corals, Bivalves and Gastropods*. Rome (IT): FAO.

Fales RJ, Boardman FC, Ruesink JL. 2020. Reciprocal Interactions between Bivalve Molluscs and Seagrass: A Review and Meta-Analysis. *Journal of Shellfish Research*. 39(3): 547-562. DOI: https://doi.org/10.2983/035.039.0305.

Furkon, Nessa N, Ambo-Rappe R, Cullen-Unsworth LC, Unsworth RKF. 2020. Social-Ecological Drivers and Dynamics of Seagrass Gleaning Fisheries. *Ambio: A Journal of Environment and Society*. 49: 1271-1281. DOI: https://doi.org/10.1007/s13280-019-01267-x.

Gagnon K, Rinde E, Bengil EGT, Carugati L, Christianen MJA, Danovaro R, Gambi C, Govers LL, Kipson S, Meysick L, Pajusalu L, Kzlkaya NT, Koppel JVD, Heide TVD, Katwijk MMV, Bostrom C. 2020. Facilitating Foundation Species: The Potential for Plant Bivalve Interactions to Improve Habitat Restoration Success. *Journal of Applied Ecology*. 57(6): 1161–1179. DOI: https://doi.org/10.1111/1365-2664.13605.

García-Souto D, Ríos G, Pasantes JJ. 2017. Karyotype Differentiation in Tellin Shells (Bivalvia: Tellinidae). *BioMed Central Genetics*. 18: 66. DOI: https://doi.org/10.1186/s12863-017-0535-1.

Infantes E, Hoeks S, Adams MP, van der Heide T, van Katwijk MM, Bouma TJ. 2022. Seagrass Roots Strongly Reduce Cliff Erosion Rates in Sandy Sediments. *Marine Ecology Progress Series*. 700: 1-12. DOI: https://doi.org/10.3354/meps14196.

Inoue T, Fujimura T, Noguchi K. 2024. Growth, Morphology and Respiratory Cost Responses to Salinity in the Mangrove Plant *Rhizophora stylosa* Depend on Growth Temperature. *Plant, Cell and Environment*. 48(2): 965-977. DOI: https://doi.org/10.1111/pe.15184.

Ikhsan N, Zamani NP, Soedharma D. 2019. Seagrass Community Structure in the Wanci Island, Wakatobi Regency, Province of Southeast Sulawesi. *Jurnal Teknologi Perikanan dan Kelautan*. 10(1): 27-38. DOI: https://doi.org/10.24319/jtpk.10.27-38.

Islami MM. 2013. Pengaruh Suhu dan Salinitas terhadap Bivalvia. *Jurnal Oseana*. 38(2): 1-10.

Jalaludin M, Lestari D, Andriani M, Ulum M, Mellenia SN. 2020. Korelasi antara Ekosistem Mangrove *Rhizophora stylosa* terhadap Biota Aquatik di Pulau Pramuka Kepulauan Seribu. *Jurnal Geografi*. 9(1): 38-49. DOI: https://doi.org/10.24036/geografi/vol9-iss1/944.

James RK, Silva R, van Tussenbroek BI, Escudero-Castillo M, Mariño-Tapia I, Dijkstra HA, van Westen RM, Pietrzak JD, Candy AS, Katsman CA, van der Boog CG, Riva REM, Slobbe C, Klees R, Stapel J, van der Heide T, van Katwijk MM, Herman PMJ, Bouma TJ. 2019. Maintaining Tropical Beaches with Seagrass and Algae: A Promising Alternative to Engineering Solutions. *Bioscience*. 69(2): 136-142. DOI: https://doi.org/10.1093/biosci/biy154.

Junita DR, Sartimbul A, Gustiantini L, Sahudin. 2020. Study of Microfauna Foraminifera as Bioindicator for Coral Reef Condition in Tambelan Island, Riau Island Province. *The 3rd International Conference on Marine Science (ICMS) 2019 "Towards Sustainable Marine Resources and Environment", 4 September 2019, Bogor, Indonesia*. IOP Conference Series: Earth and Environmental Science.

Karimah. 2017. Peran Ekosistem Hutan Mangrove sebagai Habitat untuk Organisme Laut. *Jurnal Biologi Tropis*. 17(2): 51-57. DOI: https://doi.org/10.29303/jbt.v17i2.497.

Kawaroe M, Nugraha AH, Juraij, Tasabaramo IA. 2016. Seagrass Biodiversity at Three Marine Ecoregions of Indonesia: Sunda Shelf, Sulawesi Sea, and Banda Sea. *Biodiversitas Journal of Biological Diversity*. 17(2): 585-591. DOI: https://doi.org/10.13057/biodiv/d170228.

Lønborg C, Mller M, Butler, ECV, Jiang S, Ooi SK, Trinh DH, Wong PY, Ali SM, Chun, Wee BS, Yando ES, Friess DA, Rosentreter JA, Eyre BD, Martin P. 2021. Nutrient Cycling in Tropical and Temperate Coastal Waters: Is Latitude Making a Difference?. *Estuarine, Coastal and Shelf Science*. 262: 107571. DOI: https://doi.

org/10.1016/j.ecss.2021.107571.
Magurran AE. 2004. *Measuring Biological Diversity*. Oxford (GB): Blackwell Science Ltd.
McKenzie LJ, Yoshida RL. 2013. *Seagrass-Watch: Proceedings of a Workshop for Monitoring Seagrass Habitats in South East Queensland*. Cairns (AU): Seagrass-Watch HQ.
Natsir NA, Allifah ANA. 2020. Analisis Frekuensi dan Keragaman Bivalvia di Perairan Pantai Pulau Ay Kecamatan Banda Kabupaten Maluku Tengah. *Pattimura Proceeding: Conference of Science and Technology*. 249-258. DOI: https://doi.org/10.30598/PattimuraSci.2020.SNPK19.249-258.
Nugraha AH, Kawaroe M, Srimariana ES, Jaya I, Apdillah D, Deswati SR. 2019. Carbon Storage in Seagrass Meadow of Teluk Bakau–Bintan Island. *The 3rd EMBRIO International Workshop on Marine Biodiversity: Understanding, Utilization, Conservation, 9-10 Oktober 2018, Bogor, Indonesia*. IOP Conference Series: Earth and Environmental Science.
Rinaldi AN, Adriman, Fauzi M. 2021. Jenis dan Kelimpahan Bivalvia pada Ekosistem Mangrove di Teluk Buo Kecamatan Bungus Teluk Kabung Kota Padang. *Jurnal Sumberdaya dan Lingkungan Akuatik*. 2(1): 215-223.
Rogers TL, Kimbro DL. 2015. Causes and Consequences of Historical Multi-trophic Diversity Change in an Intertidal Seagrass Bed. *Marine Ecology Progress Series*. 540: 13-26. DOI: https://doi.org/10.3354/meps11526.
Saderne V, Geraldi NR, Macreadie PI, Maher DT, Middelburg JJ, Serrano S, Almahasheer H, Arias-Ortiz A, Cusack M, Eyre BD, Fourqurean JW, Kennedy H, Krause-Jensen D, Kuwae T, Lavery PS, Lovelock CE, Marb N, Masqu P, Mateo MA, Mazarrasa I, McGlathery KJ, Oreska MPJ, Sanders CJ, Santos IR, Smoak JM, Tanaya T, Watanabe K, Duarte CM. 2019. Role of Carbonate Burial in Blue Carbon Budgets. *Nature Communications*. 10(1): 1106. DOI: https://doi.org/10.1038/s41467-019-08842-6.
Sanmartí N, Solé L, Romero J, Pérez M. 2018. Seagrass-Bivalve Facilitative Interactions: Trait-mediated Effects Along an Environmental Gradient. *Marine Environmental Research*. 133: 99-104. DOI: https://doi.org/10.1016/j.marenvres.2017.12.002.
Switzer AD, Pile J. 2015. *Grain Size Analysis, Handbook of Sea-Level Research*. Chichester (GB): John Wiley & Sons.
Wang K, Jiang M, Li Y, Kong S, Gao Y, Huang Y, Qiu P, Yang Y, Wan S. 2024. Spatial Differentiation of Mangrove Above-ground Biomass and Identification of Its Main Environmental Drivers in Qinglan Harbor Mangrove Nature Reserve. *Sustainability*. 16(19): 8408. DOI: https:// doi.org/10.3390/su16198408.
Suminar HS, Zahidah Z, Hamdani H, Sahidin A. 2020. Distribusi Spasial Komunitas Makrozoobentos di Sungai Cilalawi Kabupaten Purwakarta, Jawa Barat. *DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir, dan Perikanan*. 9(2): 164-172. DOI: https://doi.org/10.13170/depik.9.2.14676.
Susetya IE, Hutapea ED, Manik EA, Wahyuwatri I, Aritonang JE, Saridu SA. 2022. Habitat Characteristics of Bicolor Pen Shell (Pinna bicolor) in Seagrass Ecosystems in Poncan Gadang Island, Sibolga City, Sumatera Utara. *International Conference on Agriculture, Environment and Food Security (AEFS) 2021, 18 November 2021, Medan, Indonesia*. IOP Conference Series: Earth and Environmental Science.
Suwondo, Febrita E, Siregar N. 2012. Kepadatan dan Distribusi Bivalvia pada Mangrove di Pantai Cermin Kabupaten Serdang Bedagai Provinsi Sumatra Utara. *Jurnal Biogenesis*. 9(1): 45-50. DOI: http://dx.doi.org/10.31258/biogenesis.9.1.45-50.
Tan YM, Dalby O, Kendrick GA, Statton J, Sinclair EA, Fraser MW, Macreadie PI, Gillies CL, Coleman RA, Waycott M, van Dijk K, Vergés A, Ross JD, Campbell ML, Matheson FE, Jackson EL, Irving AD, Govers LL, Connolly RM, McLeod IM, Rasheed MA, Kirkman H, Flindt MR, Lange T, Miller AD, Sherman CDH. 2020. Seagrass Restoration is Possible: Insights and Lessons from Australia

and New Zealand. *Frontiers in Marine Science*. 7: 617. DOI: https://doi.org/10.3389/fmars.2020.00617.

Thalia SD, Andania C, Kurniawan PR, Prasetyo MA, Amalia IA, Jaka SR, Aisha AN, Irsyadtyas MS, Pratiwi IA. 2021. A Comparative Study of Bivalves in Intertidal Area of Southeast Asia and Along the Coastline of Arabian Sea: A Review. *Journal Ecology, Environment, and Conservation*. 27(2): 639-644.

Voight JR. 2015. Xylotrophic Bivalves: Aspects of Their Biology and The Impacts of Humans. *Journal of Molluscan Studies*. 81(2): 175-186. DOI: https://doi.org/10.1093/mollus/eyv008.

Widasari FN, Wulandari SY, Supriyantini E. 2013. Pengaruh Pemberian *Tetraselmis chuii* dan *Skeletonema costatum* terhadap Kandungan EPA dan DHA pada Tingkat Kematangan Gonad Kerang Totok *Polymesoda erosa*. *Journal of Marine Research*. 2(1): 15-24. DOI: https://doi.org/10.14710/jmr.v2i1.2050.

Zahroh A, Riani E, Anwar S. 2019. Analisis Kualitas Perairan Kabupaten Cirebon Provinsi Jawa Barat. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan*. 9(1): 86-91. DOI: https://doi.org/10.29244/jpsl.9.1.86-91.