



The influence of planting distance on seagrass (*Enhalus acoroides*) seedling growth

Haniifah N. F. Puruhito^{1,*}, Indri Addini¹, Aditya H. Nugraha²

¹Carbonethics Indonesia, Jakarta, Indonesia.

²Marine Science Department, Raja Ali Haji Maritime University, Tanjungpinang, Indonesia

ARTICLE INFO

Keywords:

Enhalus
Growth
Seagrass
Seedlings
Spacing

ABSTRACT

Seagrass restoration practice of transplanting grown seagrass from a donor to the planting site is discovered to disrupt the existing ecosystems. An alternative method includes the use of seedlings, which requires a protected germination environment to survive. At the initial stage, the seedlings need adequate space for growth and expansion of root systems. However, cultivating seagrass seedlings in aquariums is challenging due to limited space. Therefore, this study aimed to investigate the growth and development of aquarium-cultured seagrass seedlings and evaluate the impact of different spacing on growth. Seedlings were cultivated in the laboratory under 2 treatments, each lasting 3 months. *Enhalus acoroides* seedlings collected from Dompok Island, Tanjungpinang, were used with varying planting distances for each treatment. The results showed that Treatment A (4 cm spacing) had a lower survival rate (66.73%) compared to Treatment B (1.5 cm spacing) (97.78%) due to a fungus outbreak. However, Treatment B had slower growth than A, suggesting potential problems with water quality and increased competition for resources in denser plantings. In this study, the significance of planting spacing was outlined and a statistically significant difference was discovered in seagrass growth between various treatments ($P < 0.05$). A rapid growth rate of 2.08-3.02 mm/day was observed in leaves, which exceeded the value observed in previous investigations conducted under similar conditions and species. It was important to acknowledge that leaf length was also 17.5-21.6 cm, exceeding the values observed in another experiment using lab-cultured *E. acoroides*. Root lengths were comparatively shorter (7.6-8.2 cm), which signified the dynamic nature of seagrass development. In conclusion, addressing environmental conditions and optimizing planting spacing, was essential for sustainable growth.

DOI: 10.13170/depik.13.2.37366

Introduction

Seagrass beds are crucial for maintaining the health of marine ecosystems and providing a variety of resources for humans. They are essential for nutrient and gas cycling through biogeochemical processes, offer the home to a variety of commercially valuable animals, and help control sediment transport while protecting coastlines from erosion. Additionally, these underwater meadows supply organic and inorganic matter to some parts of the marine environment, supporting the growth of other marine life.

The existence of seagrass beds is increasingly threatened by both caused by natural and human-induced damage. According to Waycott *et al.* (2009), there has been a 7% annual global decrease in the

distribution of seagrass beds since 1990. In Indonesia, human activities, such as coastal development, land reclamation, deforestation, overfishing, and garbage dumping have caused significant damage (Unsworth *et al.*, 2018). For instance, Pari Island in Thousand Islands experienced a decrease of up to 25% in the underwater meadow area between 1999 and 2004 due to rampant development (Sjafrie *et al.*, 2018). Similarly, Panjang Island in Banten experienced a 63.9% decrease due to natural stone mining, hill leveling, and coastal reclamation (Sugianti and Mujiyanto, 2020). The decrease in seagrass beds has a cascading effect on marine biodiversity, as it leads to a reduction in the diversity of marine organisms

* Corresponding author.

Email address: haniifah@carbonethics.org

that depend on seagrass for food and shelter (Riniatsih et al., 2021).

Seagrass restoration is essential to reinstate the ecological functions of seagrass beds. Several restoration methods have been adopted with varying degrees of success. The majority of practices used clonal vegetative stock transplanted from an existing bed to a new site (Orth et al., 2006; Lee and Park, 2008; van Katwijk et al., 2009). However, this can disturb the original seagrass meadow, damage climax species such as *Enhalus acoroides*, which requires a long recovery period (Calumpong et al., 2001; Irawan, 2018), and reduce genetic diversity, making the plant less resilient to stress (Williams and Orth, 1998).

Seedlings have several advantages for restoration but are rarely used. These benefits include being produced in large quantities, easily harvested and stored, less destructive, and contributing to greater genetic diversity in the restored population (Orth et al., 2006; Yue et al., 2019). However, seedlings are susceptible to environmental conditions and predation, often resulting in a high failure rate (Orth et al., 2000; Lacap et al., 2002).

To improve the success rates of *E. acoroides* seedlings' restoration, seedlings are collected or germinated in protected conditions, such as laboratory environments until the leaf, root, and rhizome are developed (Ambo-Rappe and Yasir, 2015). This method enhances the resilience to environmental conditions and predators when reintroduced into the wild.

Limited space makes growing seagrass seedlings in the laboratory challenging. While planting a large number of seagrass shoots or seedlings may be beneficial initially, the spatial arrangement is crucial for ensuring positive ecological interactions and the success of restoration efforts (Valdez et al., 2020). This implies that seedlings should be spaced to promote beneficial interactions with the surroundings. However, there is a lack of studies exploring the importance of planting distance or spatial arrangement in fostering seagrass growth. It is important to acknowledge that the optimal planting distance for seedling establishment has not been identified.

Alternative methods of seedling cultivation in the laboratory still need to be developed to produce healthy specimens similar to those in nature. An example of these methods is to grow seagrass leaf and roots in an aquarium. This study aims to investigate the growth and development of seagrass leaf and roots in an aquarium and to determine the effect of planting distance on growth.

Materials and Methods

Location and time of research

Seagrass seedlings were cultivated in the laboratory for 2 treatments in a year using *E. acoroides* seeds. Treatment A was conducted from October to December 2021, while Treatment B spanned from April to June 2022. In addition to the constraint of limited fruit availability in the field as well as restricted aquarium and laboratory space, both treatments were executed at different times to test replication over a 3-month cultivation cycle.

Fruits were collected from Dompak Island, Tanjungpinang, Riau Islands Province, Indonesia, using random sampling methods in an area primarily characterized by a sandy-muddy substrate. Fully ripened fruits selected for cultivation were distinguished based on firm stems, and rounded shapes, alongside short, non-stiff hair covering seed pods. Collection for Treatment A and B occurred on October 2-3, 2021, and March 19, 2022, respectively. In Treatment A, the harvested fruits were stored in a container inside a refrigerator, with a slight submersion in seawater. For Treatment B, fruits were kept in a container at room temperature, and also slightly submerged in seawater. Subsequently, seedlings were cultivated in the Wet Laboratory of the Faculty of Marine Science and Fisheries, Raja Ali Haji Maritime University, Senggarang, Tanjungpinang City.

Experimental Design

Cultivation was conducted in three separate aquariums (Figure 1), each of which was equipped with the same apparatus and maintained to ensure uniform seawater quality. Seedlings were embedded in a 10-cm substrate layer and spaced 4 and 1.5 cm apart for Treatments A and B, respectively.

The selection of the 1.5 and 4 cm spacing and 4 cm spacing variations was driven by several practical and ecological considerations, directly related to the study objectives. The 1.5 cm spacing was selected to efficiently utilize the experimental area, maximizing the number of seedlings observed in the available space. This variation aimed to assess the impact of close proximity on the growth and development of seagrass leaf and root. It was hypothesized that closer planting distances would result in competition for resources, potentially influencing growth patterns.

The 4 cm spacing was selected to improve airflow and movement, allowing seagrass to experience the benefits of broader circulation. This variation was designed to investigate the influence of spacing on airflow-mediated nutrient exchange and light penetration. It was hypothesized that wider spacing

would facilitate enhanced light availability, potentially promoting healthier growth and development of seagrass specimens.

Treatments A and B included cultivating 293 and 300 seedlings, respectively. Both treatments adopted an aerator for aeration, and continuous 24-hour lighting was provided through LED lights. Water changes were not performed due to the use of an aerator to sustain circulation. However, as seagrass reached greater heights, seawater was added.

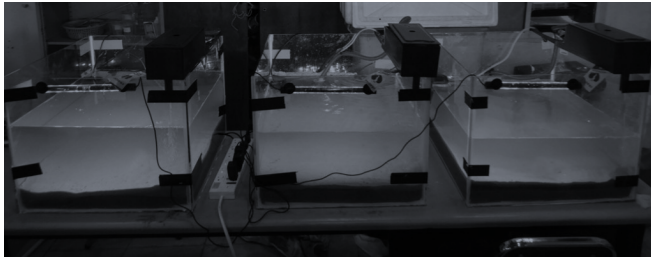


Figure 1. The three aquariums for cultivating *E. acoroides* seagrass seedlings

Data Collection

Seedlings were monitored for 3-months before being transplanted into the natural habitat. Data collected during this period included seedling growth, survival rate, and water quality. Seedling growth was assessed biweekly by measuring leaf length, leaf width, and root length, as detailed in Figure 2. Subsequently, salinity, temperature, and pH were measured using a Hand-Refractometer, thermometer, and pH meter, respectively.



Figure 2. Seagrass growth was measured biweekly using a ruler

Data Analysis

The data collected in this study were used to analyze the effects of planting distance on the growth of lab-cultured seagrass seedlings. The survival rate was calculated using the following equation (Alie, 2010).

$$SR = \frac{N_t}{N_0} \cdot 100\% \quad (1)$$

The growth rate was calculated using the following equation (Short et al., 2001).

$$GR = \frac{(L_t - L_0)}{\Delta t} \quad ((2)$$

Where:

SR : survival rate (%)

N_t : number of transplant units at time t

N_0 : number of transplant units at initial time

L_t : length at t time measurement (cm)

L_0 : length at initial time measurement (cm)

t : observation time (day)

Growth data was then analyzed using a two-way Analysis of Variance (ANOVA) test, to determine the statistical difference between the different treatments. Furthermore, an ANOVA test was performed per growth parameter.

Results

During the 3-month monitoring period, a total of 12 time-series data points were acquired for the average temperature, salinity, and pH across the three aquariums in both treatments. Treatment A showed significant fluctuations in all parameters, while Treatment B tended to remain stable for weeks. Based on comparison, the average water temperature (Figure 3), pH (Figure 4), and salinity (Figure 5) in Treatment A were relatively higher. Water was not added during Treatment A, but in Treatment B, it was added twice, specifically in the 6th and 12th weeks.

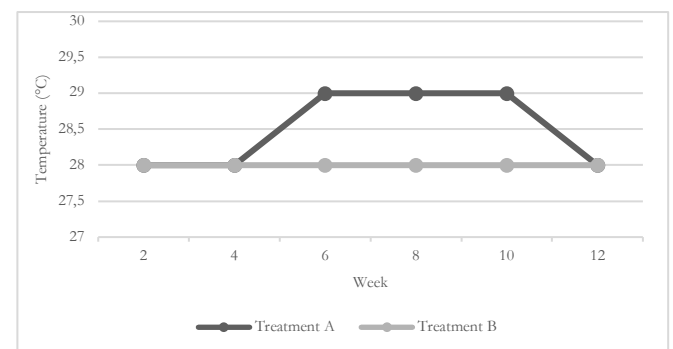


Figure 3. The average temperature of aquarium water in Treatments A and B

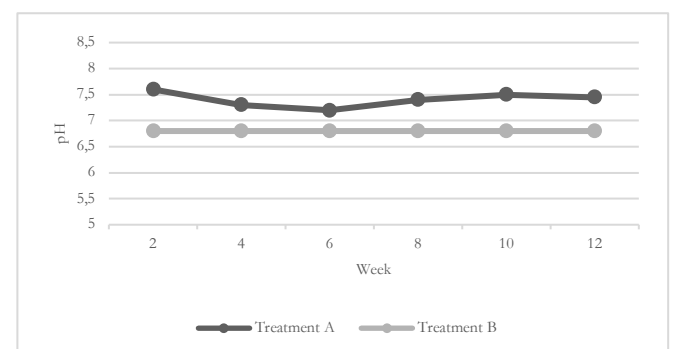


Figure 4. The average pH of aquarium water in Treatments A and B

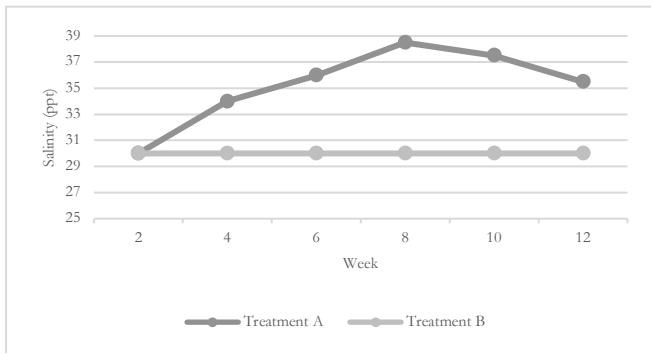


Figure 5. The average salinity of aquarium water in Treatments A and B

Survival rate increases from one treatment to another. However, several seagrass seedlings failed to grow in the observation period, presumably due to inability to adapt to the environmental conditions in the tank.

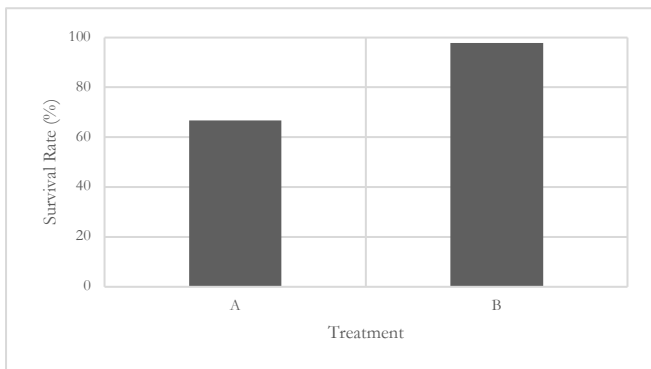


Figure 6. The survival rate of *E. acoroides* seedlings grown in seawater in the laboratory

Survival rates in Treatment A and B were 66.73% and 97.78%, respectively, as detailed in Figure 6. This discrepancy was attributed to the identification of fungus on certain seagrass seedlings during Treatment A, leading to widespread mortality.

Based on 50 data points extracted from each treatment, the growth graph of seagrass seedlings showed a progressive trend in weeks. However, the overall growth in Treatment B was slower in terms of leaf length, leaf width, and root length compared to Treatment A.

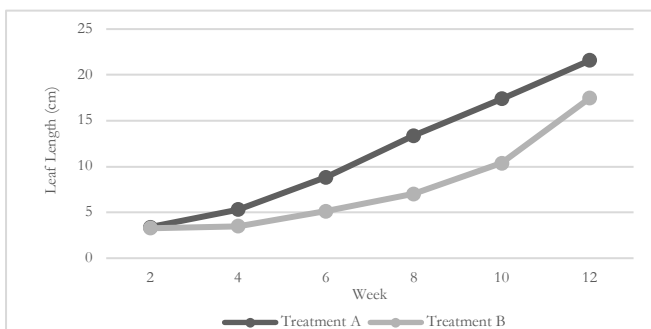


Figure 7. Growth of *E. acoroides* leaf length in two treatments over 12 weeks

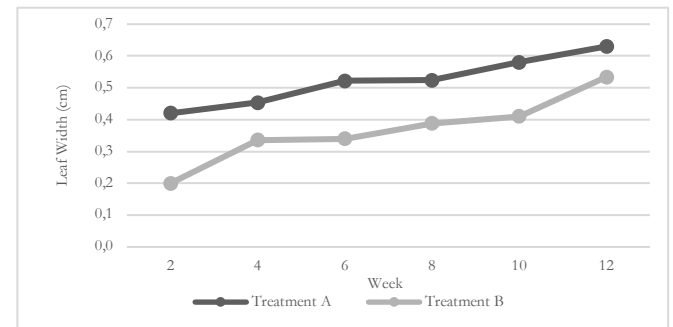


Figure 8. Growth of *E. acoroides* leaf width in two treatments over 12 weeks

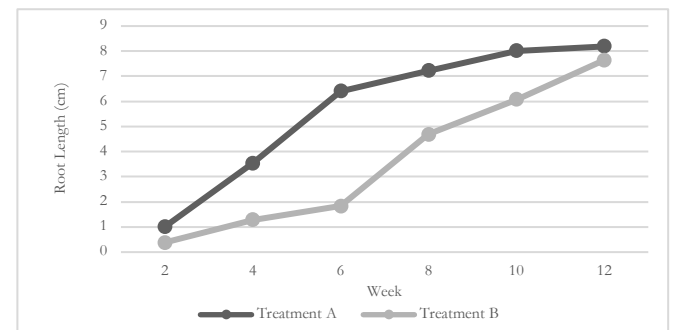


Figure 9. Growth of *E. acoroides* root length in two treatments over 12 weeks

The calculations on the average daily growth rate of seagrass seedlings, as detailed in Table 1, showed that the most significant variation existed in the expansion of the leaf, reaching 0.488 mm/day, compared to other parameters.

Table 1. Average growth rate* of *E. acoroides* in two treatments over 12 weeks

Treatment	Average growth rate (mm/day)		
	Leaf width	Leaf length	Root length
A	0.075	2.567	0.975
B	0.064	2.079	0.910

Seagrass development showed statistically significant differences in growth between the treatments at a 95% confidence level, as presented in Table 2.

Table 2. Two-way ANOVA results of seagrass growth with spacing per growth parameter

Leaf width					
Source	SS	Df	MS	F	P-value
Rows	0.085	5	0.016924	16.3058	0.004093
Columns	0.071	1	0.07084	68.25133	0.000424
Total	0.161	11			
Leaf length					

Source	SS	Df	MS	F	P-value
Rows	380.11	5	76.022	22.19457	0.002001
Columns	44.82	1	44.82241	13.08587	0.015261
Total	442.06	11			

Root length					
Source	SS	Df	MS	F	P-value
Rows	78.038	5	15.6076	14.25903	0.005559
Columns	12.979	1	12.9792	11.85773	0.018366
Total	96.490	11			

Discussion

The aquarium water in Treatment A met water quality standards for seagrass in terms of average temperature and pH levels, as defined by the Minister of State for the Environment Decree Number 51 of 2004 concerning seawater quality. In Treatment B, while the average pH was in the acceptable range, the temperature dropped below the recommended quality threshold. Fahrudin et al. (2017) stated that the salinity levels of Treatment A and B were 35 ppt and 29 ppt, respectively.

During the study, there was an overall improvement in survival rate between successive treatments. However, some seedlings showed persistent failure to thrive, potentially attributed to challenges in adapting to environmental conditions in the tank, including factors such as water temperature, salinity, pH, and the presence of growth-inhibiting substances. It is important to acknowledge that external factors, such as the transfer and storage of seagrass fruits also contribute to these observed outcomes.

Fungus was observed on some of seagrass seedlings in Treatment A causing mass death, leading to a poor average survival rate of 66.73%. This was attributed to the incorrect way of storing fruits before cultivation. During this treatment, fruits were stored in a refrigerator for up to 1 day in a slightly submerged seawater condition. The low temperature of the refrigerator hampered and damaged seagrass seedlings, including the storage reserves (Ambo-Rappe and Yasir, 2015).

Ambo-Rappe and Yasir (2015) identified the effect of storage conditions on the observed survival rate. According to the study, there is a correlation between storage temperature and the viability of seedlings. At room temperature of approximately 30°C, seedlings showed better germination and growth compared to those stored in a refrigerator of 4°C. This connection signified the potential impact of storage conditions on the survival rate observed in Treatment A, where fruits were refrigerated and subsequently infected with fungus, compared to Treatment B.

In this study, seagrass leaf grew at a faster rate (2.08-3.02 mm/day) compared to those cultivated by Nugraha et al. (2021) under similar conditions (0.90 mm/day). Tongnunui et al. (2016) reported *E. acoroides* seagrass seedlings grown in laboratories having leaf lengths of 10-16 cm and root lengths of 9-13 cm after 12 weeks. However, in this study, longer leaf of 17.5-25.4 cm and shorter roots of 7.6-10.1 cm were observed. The difference could be due to several factors, including the availability of nutrients (Unsworth et al., 2022), the type of substrate used, and the water movement systems in the aquarium. Morphometric differences in seagrass can also be caused by variations in seed quality, such as size (Artika et al., 2020; Tan et al., 2023). The availability of food reserves in seedlings is essential for growth, which supports the development process of seagrass (Lesilolo et al., 2013). This suggests that the differences in seagrass growth rate can be influenced by the characteristics of the study site and variations in the circumstances of each treatment.

Compared to seagrass which grows naturally in Bintan waters (3.92 mm/day) (Salahuddin et al., 2022), the leaf length of the cultivated species had a slower growth rate of 2.08-3.02 mm/day. This could be attributed to a limited substrate in the aquarium substrate and the lack of nutrient addition. Nutrients available were only those present in the aquarium substrate. In contrast, currents in the wild transport nutrients from various sources, providing seagrass with a more constant supply of essential elements (Nugraha et al., 2021).

In this study, the initial seedlings were half-buried in the substrate. The planting depth can impact the germination cues or energy stores of seedlings to reach the surface, affecting the germination rates (Wang et al., 2016; Cumming et al., 2017). The experiment conducted by Li et al. (2021) showed that the young leaf of plants placed on the surface of the substrate grew faster than those half and completely buried. The planted *Enhalus* seedlings could not access enough light or oxygen, which are essential factors for germination and growth (Li et al., 2021).

In this study, a substrate used for seedling cultivation was sand. The composition of the sediment affected seed germination, seedling growth, and root development. The slow rate of root growth could be caused by the larger grain size of sand in substrate, or root development inhibitor (Li et al., 2021).

Seagrass growth rate in Treatment B was slower than in Treatment A. This could be attributed to the impact of poor seawater quality. Despite *Enhalus* having a wide salinity tolerance range, the salinity of

Treatment B (30 ppt) was lower than the optimum threshold of 35 ppt for seagrass growth (Parakkasi et al., 2019).

pH of the water in Treatment B (stable at 6.8) was very low for optimal seagrass growth. This is because the bicarbonate ions required for photosynthesis were more abundant at higher pH levels of 7.5-8.5 (Rosmawati et al., 2020). Andika et al. (2023) stated that seagrass leaf growth rate was significantly elevated in a range of 7.78-8.20 compared to environments with lower levels of 7.55. This disparity was attributed to the adverse impact of low pH on seagrass leaf, which indirectly interfered with chlorophyll levels by affecting nitrate availability (Andika et al., 2020), a vital nutrient for leaf development (Kawaroe et al., 2016). Consequently, seagrass leaf in Treatment B had a lower growth rate compared to those in Treatment A, which maintained pH levels between 7.2 and 7.6.

In Treatment B, seagrass leaf and root were shorter and smaller in size due to excessive planting density and narrow spacing compared to other treatments. Seagrass grows both vertically and horizontally, with the blades reaching upwards and the root extending downward and sideways to capture sunlight and nutrients from the water and sediment. Consequently, when planted closely together, the plant engages in competitive interactions for space and essential resources (Tasabaramo et al., 2015).

This study did not include extra nutritional supplementation in the form of fertilizers or other growth-promoting substances. The narrow planting spacing of 1.5 cm and the lack of nutritional assistance, possibly intensified competition between seagrass seedlings in Treatment B for critical resources, including space and essential nutrients for growth. Consequently, this combination of factors led to the observed inability of seedlings to achieve the same size and growth rate.

According to the statistical analysis of seagrass growth in two cultivation treatments, spacing between the plantings significantly affected the growth of the leaf and root. The results showed a statistically significant difference in seagrass growth between the various spacing treatments, with a 95% confidence interval. This signified that planting spacing is a vital factor to consider in terms of growth. The results also showed significant variation in seagrass growth in weeks.

Conclusion

In conclusion, this study showed that Treatment A (4 cm spacing) had a lower survival rate (66.73%)

compared to Treatment B (1.5 cm spacing) (97.78%) due to a fungus outbreak. However, Treatment B exhibited a had seagrass growth rate compared to Treatment A, possibly due to poor water quality and increased competition for resources in the denser planting. This study identified the significance of planting spacing, presenting a statistically significant difference in seagrass growth between various spacing treatments ($P < 0.05$). Therefore, addressing environmental conditions and optimizing planting spacing were crucial factors in promoting growth and sustainability.

A rapid growth rate of seagrass leaf, ranging from 2.08 to 3.02 mm/day was observed. This value significantly exceeded previous results under similar conditions and species. A longer leaf (17.5-21.6 cm) but shorter root (7.6-8.2 cm) was also discovered, in comparison to another similar experiment using lab-cultured *E. acoroides* in the same observation period. Surpassing previous studies, these results outlined the dynamic nature of seagrass development.

This study provided valuable insights into seagrass growth dynamics and the impact of planting spacing. However, further investigations should focus on refining environmental conditions and planting density for a more comprehensive understanding. Extended observation periods, inclusion of diverse seagrass species, and exploration of additional planting distances would contribute to a more nuanced comprehension of seagrass development and inform sustainable practices for the cultivation of the plant.

Acknowledgments

This study was conducted as part of the Bintan Seagrass Cultivation Project, a collaboration between Carbon Ethics and Raja Ali Haji Maritime University. The authors are grateful to Microgrant SOA 2021 for funding this study. The authors are also grateful to Zulpikar, Trinanda Zulmi, Rajib, Ramona Destrica, Anifa Yuniasri, Zuhrotul Lailiah, Widia Kartika Di Sari. P, Carla Dhevandha, local government, and local community for supporting this study and helping during fieldwork.

References

- Alie, K. 2010. Pertumbuhan dan Biomassa Lamun *Thalassia hemprichii* di Perairan Pulau Bone Batang, Kepulauan Spermonde, Sulawesi Selatan. *Jurnal Sains MIPA*, 16(2): 105-110.
- Andika, Y., M. Kawaroe, H. Effendi, N. P. Zamani. 2020. Pengaruh Kondisi pH Terhadap Respons Fisiologis Daun Lamun Jenis *Cymodocea rotundata*. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 12(2): 487-495.
- Andika, Y., M. Kawaroe, H. Effendi, N. P. Zamani, Erniati, Erlangga, S. Adhar, Imanullah, Imamshadiqin, C. M. N. 'Akla, A. Sugara, B. T. K. Ilhami. 2023. The Effect of Differences pH of Waters on

- The Growth Rate of Seagrass of *Cymodocea rotundata*. J. Ilmu dan Teknologi Kelautan Tropis, 15(1):99-111.
- Ambo-Rappe, R., I. Yasir. 2015. The effect of storage condition on the viability of *Enhalus acoroides* seedlings. Aquatic Botany, 127: 57-61.
- Artika, S. R., R. Ambo-Rappe, M. Teichberg, A. Moreira-Saporiti, I. G. Viana. 2020. Morphological and Physiological Responses of *Enhalus acoroides* Seedlings Under Varying Temperature and Nutrient Treatment. Frontiers in Marine Science, 7(325): 1-19.
- Calumpang, H. P., M. S. Fonseca. 2001. Seagrass transplantation and other seagrass restoration methods. In: Short, F. T., R. G. Coles (eds.), Global Seagrass Research Methods. Elsevier Sci. Publ., Amsterdam, pp. 425-443.
- Cumming, E., J. C. Jarvis, C. D. H. Sherman, P. H. York, T. M. Smith. 2017. Seed germination in a southern Australian temperate seagrass. PeerJ, 5:1-19.
- Fahrudin, M., F. Yulianda, I. Setyobudiandi. 2017. Kerapatan dan Penutupan Ekosistem Lamun di Pesisir Desa Bahoi, Sulawesi Utara. Jurnal Ilmu dan Teknologi Kelautan Tropis, 9(1): 375-383.
- Irawan, A. 2018. Transplantation of *Enhalus acoroides* on a sedimentary beach in Ambon Bay. IOP Conference Series: Earth Environmental Science, 118: 1-6.
- Kawaroe, M., A. H. Nugraha, Juraji. 2016. Ekosistem Padang Lamun. IPB press, 114.
- Lacap, C. D. A., J. E. Vermaat, R. N. Rollon, H. M. Nacorda. 2002. Propagule dispersal of the S.E. Asian seagrasses *Enhalus acoroides* and *Thalassia hemprichii*. Marine Ecology Progress Series, 235: 75-80.
- Lee, K. S., J. L. Park. 2008. An effective transplanting technique using shells for restoration of *Zostera marina* habitats. Marine Pollution Bulletin, 56(5): 1015-1021.
- Lesilolo, M. K., J. Riry, E. A. Matatula. 2013. Pengujian Viabilitas dan Vigor Benih Beberapa Jenis Tanaman yang Beredar di Pasaran Kota Ambon. Agrologia, 2(1).
- Li, H., J. Liu, X. Che. 2021. Establishing healthy seedlings of *Enhalus acoroides* for the tropical seagrass restoration. Journal of Environmental Management, 286: 1-10.
- Menteri Negara Lingkungan Hidup. 2004. Keputusan Menteri Negara Lingkungan Hidup Nomor 51 Tahun 2004 tentang Baku Mutu Air Laut, Jakarta.
- Nugraha, A. H., S. Almahdi, A. Zahra, I. Karlina. 2021. Morphometric Characteristic and Growth Responses of *Enhalus acoroides* Seedlings Under Different Substrate Composition Treatment. Omni-Akuatika, 17(2): 112-117.
- Orth, R. J., M. C. Harwell, E. M. Bailey, A. Bartholomew, J. T. Jawad, A. V. Lombana, K. A. Moore, J. M. Rhode, H. E. Woods. 2000. A review of issues in seagrass seed dormancy and germination: implications for conservation and restoration. Marine Ecology Progress Series, 200: 277-288.
- Orth, R. J., M. L. Luckenbach, S. R. Marion, K. A. Moore, D. J. Wilcox. 2006. Seagrass Recovery in the Delmarva Coastal Bays, USA. Aquatic Botany, 84(1): 26-36.
- Orth, R. J., T. J. B. Carruthers, W. C. Dennison, C. M. Duarte, J. W. Fourqurean, K. L. Heck, A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, S. Olyarnik, F. T. Short, M. Waycott, S. L. Williams. 2006. A Global Crisis for Seagrass Ecosystems. BioScience, 56(12): 987-996.
- Parakkasi, P., C. Rani, R. Syamsuddin, Najamuddin. 2019. Influence of seaweed farming on the growth of the seagrass *Enhalus acoroides*. IOP Conference Series: Earth and Environmental Science, 25: 1-7.
- Riniatsih, I., A. Ambariyanto, E. Yudiati. 2021. Keterkaitan Megabentos yang Berasosiasi dengan Padang Lamun terhadap Karakteristik Lingkungan di Perairan Jepara. Jurnal Kelautan Tropis, 24(2): 237-246.
- Rosmawati, N. V. Huliselan, A. S. Khouw, C. I. Tupan. 2020. Laju Pertumbuhan Lamun *Enhalus acoroides* yang Di Transplantasi dengan Menggunakan Metode Terfs Di Perairan Desa Waai Kabupaten Maluku Tengah. Jurnal Biology Science & Education, 9(1): 69-80.
- Salahuddin, T. Apriadi, W. Muzammil. 2022. Pertumbuhan Lamun *Enhalus acoroides* Di Perairan Desa Pangkil Kecamatan Teluk Bintan Kabupaten Bintan. Jurnal Kelautan, 15(1): 31-38.
- Short, F. T., R. G. Coles, C. Pergent-Martini. 2001. Global seagrass distribution. In: Short, F. T., R. G. Coles (eds.), Global Seagrass Research Methods. Elsevier Sci. Publ., Amsterdam, pp. 5-30.
- Sjafrie, N. D. M., U. E. Hernawan, B. Prayudha, I. H. Supriyadi, M. Y. Iswari, Rahmat, K. Anggraini, S. Rahmawati, Suyarso. 2018. Status Padang Lamun Indonesia 2018. Pusat Penelitian Oseanografi, Lembaga Ilmu Pengetahuan Indonesia, Jakarta.
- Sugianti, Y., Mujiyanto. 2020. Current Status and Species Diversity of Seagrass in Panjang Island, Banten. Indonesian Journal of Marine Sciences, 25(1): 15-22.
- Tan, Y. M., R. A. Coleman, P. A. Biro, O. Dalby, E. L. Jackson, L. L. Govers, J. H. T. Heusinkveld, P. I. Macreadie, M. R. Flindt, J. Dewhurst, C. D. H. Sherman. 2023. Developing seed- and shoot-based restoration approaches for the seagrass, *Zostera muelleri*. Restoration Ecology, 31(5): 1-13.
- Tasabaramo, I. A., M. Kawaroe, R. A. Rappe. 2015. Laju Pertumbuhan, Penutupan, dan Tingkat Kelangsungan Hidup *Enhalus acoroides* Yang Ditransplantasi Secara Monospesies dan Multispesies. Jurnal Ilmu dan Teknologi Kelautan Tropis, 7(2): 757-770.
- Tongnunui, P., W. Tarangkoon, P. Hukiew, P. Kaopraikan, M. Horinouchi, N. Rojchanaprasart, W. Ponpai. 2016. Seagrass Restoration: An Update from Trang Province, Southwestern Thailand. In: Proceedings of the 11th EMECS – Sea Coasts XXVI Joint Conference, 22-27 August 2016, St. Petersburg, Russia.
- Unsworth, R. K. F., R. Ambo-Rappe, B. L. Jones, Y. A. La Nafie, A. Irawan, U. E. Hernawan, A. M. Moore, L. C. Cullen-Unsworth. 2018. Indonesia's globally significant seagrass meadows are under widespread threat. Science of the Total Environment, 634: 279-286.
- Unsworth, R. K. F., S. C. Rees, C. M. Bertelli, N. E. Esteban, E. J. Furness, B. Walter. 2022. Nutrient additions to seagrass seed planting improve seedling emergence and growth. Frontiers in Plant Science, 13: 1-8.
- Valdez, S. R., Y. S. Zhang, T. van der Heide, M. A. Vanderklift, F. Tarquinio, R. J. Orth, B. R. Siliman. 2020. Positive Ecological Interactions and the Success of Seagrass Restoration. Frontiers in Marine Science, 7(91): 1-11.
- van Katwijk, M. M., A. R. Bos, V. N. de Jonge, L. S. A. M. Hanssen, D. C. R. Hermus, D. J. de Jong. 2009. Guidelines for seagrass restoration: importance of habitat selection and donor population, spreading of risks, and ecosystem engineering effects, Marine Pollution Bulletin, 58(2): 179-188.
- Wang, M., Y. Wang, X. Gui, J. Sha, H. Zhang, X. Tang, B. Zhou. 2016. Reproductive properties of *Zostera marina* and effects of sediment type and burial depth on seed germination and seedling establishment. Aquatic Botany, 134: 68-74.
- Waycott, M., C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnik, A. Calladine, J. W. Fourqurean, K. L. Heck Jr., A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, F. T. Short, S. L. Williams. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. In: Proceedings of the National Academy of Sciences of the United States of America, 106(3): 12377-12381.
- Williams, S. L., R. J. Orth. 1998. Genetic Diversity and Structure of Natural and Transplanted Eelgrass Populations in the Chesapeake and Chincoteague Bays. Estuaries, 21: 118-128.
- Yue, S., Y. Zhou, Y. Zhang, S. Xu, R. Gu, S. Xu, X. Zhang, P. Zhao. 2019. Effects of salinity and temperature on seed germination and seedling establishment in the endangered seagrass *Zostera japonica* Asch. & Graebn. in northern China. Marine Pollution Bulletin, 146: 848-856.

How to cite this paper:

Puruhito, H. N. F., I. Addini, A. H. Nugraha. 2024. The influence of planting distance on lab-cultured seagrass growth. Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, 13(2): 274-280.