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Current Trends in Seagrass Research in Indonesia (2010-2020)

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Abstract

Seagrass is a higher plant (Anthophyta) that lives and grows immersed in the marine environment. Seagrass provides important ecosystem services include coastal protection, carbon absorption for climate change mitigation, nutrient storage for eutrophication mitigation and shelter for small fish, and high biodiversity conservation efforts for iconic endangered species. The current lack of global attention, therefore seagrass research is important to increase knowledge on a local and national scale. Given the extent of seagrass beds and the length of Indonesia's coastline which ranges 95,181 km, so it still needs to understand seagrass more deeply, because this is very important for conservation and restoration. The purpose of this review article is to comprehensively review research on seagrass in Indonesia in five years that expected to provide a future perspective for seagrass research in Indonesia. In the publication regarding seagrass studies in Indonesia, there are 7 categories of topics discussed, distribution and biology, plant physiology, microbial ecology, fauna, impacts and potential, carbon absorption, and restoration. In general, the focus on seagrass research in Indonesia includes seagrass species, seagrass communities, nutrient cycles in seagrass ecosystems, physiology, and the impact of pollution on seagrass habitats. The results presented in seagrass research in Indonesia are still quite descriptive and lagging when compared to studies that have been carried out in developed countries. The developed countries have developed new methods for seagrass restoration activities to new knowledge about seagrass genetics that has never been disclosed previously..

1. INTRODUCTION

Seagrass is a higher plant (Anthophyta) that lives and grows immersed in the marine environment [1]. The total species of seagrass in the world is around 60 species from 5 families and 13 genera [2] [3]. The distribution of seagrass globally is most commonly found in the tropics Indo-pasific, especially in Southeast Asia with a total of 17 species [3] [4]. One of them in Southeast Asia has a big potential for seagrass ecosystems, namely Indonesia, which found 13 species of seagrass [4] [5] [6]. Seagrass area in Indonesia is 150.693,16 ha, with detail in area eastern Indonesia 146.283,68 ha, while in western Indonesia only 4.409.48 ha [7]. Although the area of seagrass in western Indonesia is lower instead eastern Indonesia, the distribution of the number of seagrass species in Indonesia is mostly found in western Indonesia, especially in the Riau Islands and Bangka Belitung Islands [7] [8]. Distribution of seagrass in Kepulauan Bangka Belitung has been reported found in Central Bangka, South Bangka and East Belitung [9] [10] [11].

Seagrass provides important ecosystem services include coastal protection, carbon absorption for climate change mitigation, nutrient storage for eutrophication mitigation and shelter for small fish, and high biodiversity conservation efforts for iconic endangered species [11] [12]. The current lack of global attention, therefore seagrass research is important to increase knowledge on a local and national scale. In Indonesia, seagrass research has increased over the past two decades, but is still relatively limited when compared to the large coastline and the enormous pressure on seagrass ecosystems. To further conserve seagrass in Indonesia, there is an urgent need to expand knowledge about seagrass beds on a local and national scale. Given the extent of seagrass beds and the length of Indonesia's coastline which ranges 95,181 km, so it still needs to understand seagrass more deeply, because this is very important for conservation and restoration [11]. The purpose of this review article is to comprehensively review research on seagrass in Indonesia in five years that is expected to provide a future perspective for seagrass research in Indonesia..

2. THE GENERAL TREND IN RESEARCH PUBLISH OF SEAGRASS IN INDONESIA

We collect publications about seagrass studies in Indonesia from https://garuda.ristekbrin.go.id/ by entering keyword seagrass on the search field. The total was found 592 articles that published in the period 2010 to 2020. We took the amount of research data on each topic of discussion from several journal of seagrass research in Indonesia (Figure 1). The publications collected are sorted into 7 categories based on the topics covered (Table 1). The 7 categories are: Distribution and Biology, Plan Physiology, Microbial Ecology, Fauna, Impact and Potency, Carbon Absorption and restoration (Table 1).

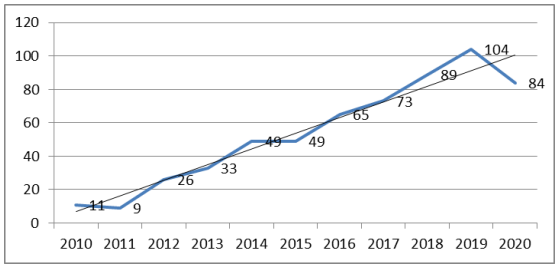

Figure 1. Seagrass publication trends in Indonesia.
(Source. garuda.ristekbrin.go.id)

Table 1. Categories of seagrass research publications in Indonesia from 2010-2020 with keywords for each category.

Category	Keyword
Distribution and Biology	Community of structure, diversity, dynamics, species composition, remote sensing distribution
Plan physiology	Anti-bacterial, phytochemical, biomass, productivity
Microbial	Heterotrophic bacteria,

ecology	fungi, proteolytic bacteria, associations
Fauna	Infauna, periphyton, associations, microalgae, macrozoobenthos
Impact and potency	Ecotourism, carrying capacity, economic value, ecosystem services
Carbon absorption	Biomass, carbon stock
Restoration	Transplantation, growth rate

The number of publications on seagrass studies from Indonesia has been low in recent years but has increased in quantity every year. The number of publications of 59,2 articles per year from 2020 till 2021 with the most publications in 2019 as many as 104 publications, this is still relatively slightly if you look at Indonesia's long coastline of 99,000 km. Another source, namely the Indonesian Scientific Journal Data Base or LIPI, reports publications on seagrass are very low at only 11.4 publications per year, the number is far from the publications on mangroves which reach 63.2 publications per year.

In general, the focus on seagrass research in Indonesia includes seagrass species, seagrass communities, and nutrient cycles in seagrass ecosystems, physiology, and the impact of pollution on seagrass habitats. The results presented in seagrass research in Indonesia are still quite descriptive and lagging when compared to studies that have been carried out in developed countries. The developed countries have developed new methods for seagrass restoration activities to new knowledge about seagrass genetics that has never been disclosed previously [13] [14] [15] [16].

Seagrass analysis and research need to be directed from descriptive studies of seagrass species and distribution to more complex studies that apply new technologies to address processes and mechanisms in seagrass biology and ecology and there needs to be an increased focus on impact studies and efforts on the restoration of seagrass ecosystems. Amidst the weakness of seagrass research results in Indonesia, topics related to seagrasses such as carbon absorption, molecular biology of plants, and genetics are relatively new in seagrass research trends in Indonesia. The waters of Java island are the most studied areas for seagrass research in Indonesia. Jepara, Karimun Jawa, and Bali areas include all the categories described in table 1. Enhalus acoroides and Thalasssia hemprichii are widely studied seagrass species.

Distribution and Biology

These distribution and biology categories include coverage of areas assessed based on current techniques (e.g. remote sensing and sonar detection), population dynamics, identification of new species, plant biology, and seagrass health assessments. Seagrass distribution is widely studied in the waters of Java island because the activity on the mainland is very busy which will directly affect the activity of the waters [17] [18]. Seagrass research project in Indonesia focuses on finding out ideal environmental conditions that can support the development of seagrasses, such as nitrate content (NO_3) and phosphate (PO_4) [19] [20], depth relationship [18] or estimation with distribution by remote sensing [21] [10].

Some studies explore the relationship between environmental factors and seagrass changes that depend on the time observed. However, many seagrass distribution studies refer to common pressures such as coastal development, tourism activity [19] [22], port activity [17], and other causes that may result in seagrass degradation. Such activity can result in sedimentation in the water resulting in changes in the depth of the water. The depth of the water contributes depth as well which will affect the current speed, turbidity, and temperature of the waters which will affect the density of seagrass [23] [24]. The general conclusion of publications in this category is to provide new information on the data collection of seagrass species in some

areas as well as concerns about threats to seagrasses given the high human pressure in coastal areas and the need for proper management to preserve existing seagrass fields and especially newly discovered ones.

Plant Physiology

The category of plant physiology includes many new methods to explore plant physiology and genetics, following rapid developments in molecular biology over the past two decades. Physiological and genetic studies have expanded knowledge about genetic diversity in more related seagrass species as well as knowledge of connectivity between seagrass populations. Genetic information is considered useful for seagrass restoration [25] [26].

Seagrass is a favorite food of protected herbivores such as green turtles and dugongs. The existence of seagrass and knowing the speed of its growth becomes very important for the sustainability of the two herbivores [27]. In addition to conservation purposes, seagrass physiology research is also widely used for human purposes. The use of seagrass leaf extract as an anti-bacterial compound is one of the uses of seagrass for humans. As [28] *Cymodocea rotundata* is a type of seagrass that has the potential as an antibacterial. Bioactive compounds that are antibacterial are phenols, flavonoids, and tannins. Similar results were also reported by [29] that the roots and leaves of seagrass *Cymodocea rotundata, Enhalus acoroides, Thalassia hemprichii, Halophila ovalis, Halophila minor, Halodule uninervis* and *Sryngodium isoetifolium* contain flavonoid, alkaloid and steroid chemicals that have the potential as natural antifouling, antibacterial, and anti-fungi. Seagrass can inhibit free radicals, but its ability is so weak that it is not potential when used as a source of natural antioxidants [30].

The use of seagrass is not limited to antibacterial and anti-fungi capabilities. As Mihrawati (2003) in [31] claimed that on the leaves, rhizoma and seagrass root (*E. acoroides*) found the presence of phytosterol compounds in the form of stigmasterol. Phytosterols are most commonly found on the leaves. Phytosterols are now widely used as an antifertility ingredient and as the raw material for contraceptive drugs. It is similarly reported by [32] that phytosterols exert an influence on increasing the weight of the testes, epididymis, and seminal vesicles. Phytosterols of seagrass plants also influence the decrease in sperm count and increased mortality of male mice sperm, thus giving the influence of decreased conception power of male mice.

The use of seagrass is diverse and potential to be developed in the future to have a positive impact on seagrass conservation activities in Indonesia. Maintaining a seagrass ecosystem also means supporting the advancement of researches in the field of seagrass utilization for human benefit. Research on seagrass physiology should continue to explore more potential of seagrass plants that have not yet been revealed.

Microbial Association of Seagrass

The number of publications discussing microbial associations in seagrass is relatively slight. This category focuses on the identification of bacteria and fungi associated with seagrass. Seagrass which is a primary producer or that occupies trophic one in the food chain system is utilized by herbivorous biota but is more utilized by feeder detritus. One of the detritus feeders that is important for the survival of seagrass ecosystems is heterotrophic bacteria which are decomposing bacteria [33] [34]. Similar research was also conducted by [35], who said increasing seagrass density can also increase the abundance of heterotrophic bacteria. In addition to bacteria found fungi associated with seagrass. The genus Aspergillus, Acremonium, Denrobium, Sclerotium, and Rhizopus are found to be associated with seagrass type *T. hemprichii* [36].

Fauna

Fauna categories include studies of epifauna, infauna, and food webs, as well as biodiversity and the role of seagrass as a food source for other organisms. Fauna studies in seagrass fields in Indonesia can be divided into four categories: 1) identification of new species; 2) study of food webs; 3) benthic invertebrates in seagrass sediment and 4) herbivores in seagrass and its epiphytes.

In the study, [37] described the relationship of seagrass density with the abundance of sea cucumbers. He pointed out the effect of seagrass density on the abundance of sea cucumbers which has a correlation value of 0.80 and a determination value of 0.641 which means that 64.1% of the abundance of sea cucumbers is influenced by seagrass density. Similarly, [38] stated that there is a close correlation so that the higher the density of seagrass will be followed by the abundance of sea cucumbers as well as other invertebrate groups [39] [40]. The important role of the seagrass ecosystem as a nursery ground for fish juveniles, especially in providing shelter and food in the early stages of fish life. All researchers agree that there is a strong link between seagrass density and the abundance of fish larvae [41] [42] [43] [44].

Studies of benthic infauna have focused on the comparison between spatial and temporal changes. As [45] stated, there is a difference in the abundance of macrozoobenthos during full moons and bandages. [46] also explained that there is no effect of water depth on the abundance of epifauna in seagrass. Organic matter of sediment and heavy metal levels also do not affect the abundance of infauna in seagrass [47] [48] [49]. In general, it is concluded that seagrass density is the main factor to be able an abundance of fauna. Research data on diversity and fauna distribution patterns in seagrass ecosystems and periodic observations need to be made because fauna belongs to the food chain system in the ecosystem and can be included as a criterion for the concept of coastal area management policy. Authors also suggest that the restoration of seagrass fields may improve the cultivation of sea cucumbers for nutritional and medical purposes as tripang products have been widely developed today.

Impact and Potency

Research on impacts and potentials generally provides an overview of the socio-economic condition of the community and ecological status, the condition of coastal ecosystems, especially seagrass structures as well as the threat of coastal ecosystems and the threat of solid waste around seagrass conservation areas. The study of seagrass ecosystem potential is more associated with the development of marine ecotourism. According to [50] Ecological parameters, seagrass vegetation structure, types of aquatic organisms strongly support marine ecotourism in the conservation area of seagrass trikora, Bintan, Riau Islands. The Tourism Suitability Index (TSI) is at a very suitable value, with a Tourism Carrying Capacity (TCC) of 25,083 people per day or 175,581 people per week. Seagrass ecosystem services are generally utilized for fishing, aquaculture, and marine tourism [51] while paying attention to the supporting capacity of the ecosystem [52]. In addition to the potential that can be utilized from seagrass ecosystems, there are also threats such as pollution, degradation of coastal ecosystems, and degradation of biota. Threats stemming from the development of marine ecotourism areas in the form of the construction of hotels, inns, and resorts and their facilities, due to tourist activities, fishing activities, and local residents [53].

Carbon stocks

Research on carbon sequestration has been conducted relatively much. Research is directed by examining the ability of seagrasses in absorbing carbon and acting as a Blue Carbon ecosystem. The issue of blue carbon has become the attention of the world, through the concept of [54] which has included seagrass vegetation as a carbon absorber in the oceans. Carbon sequestration

is stored through sediment and tissues in seagrass in the form of biomass.

Total carbon reserves stored in Indonesia's seagrass ecosystem reached 1,005-kilo tons of carbon with a potential carbon absorption of 7.4 mega tons of carbon per year. Indonesia's average seagrass carbon reserves are recorded at a maximum of 0.36 and 0.79 tons of carbon per hectare, respectively for upper and subsurface carbon reserves [55]. Many studies have suggested that carbon reserves were found to be more below substrates looking at the fact that the authors emphasized that more research is needed to understand the mechanisms behind carbon burial [56] [57] [58] [59]. Seagrass capability in carbon sequestration will support mitigation efforts in reducing the impact of Indonesia's climate change. Integrated management of coastal and marine ecosystems is important to maintain the presence of seagrass so that the contribution to the surrounding ecosystem is more stable.

Restoration

Due to the decline of seagrass cover in the world, many studies focus on the restoration of seagrass in lost habitats but the same is not true in Indonesia. This category is one of the relatively few categories discussed. Studies on seed coverage and large-scale restoration projects need to get attention to support efforts to restore seagrass ecosystems in the future.

Experiments on the right methods used for seagrass restoration efforts need to be developed. Several studies have suggested various methods of seagrass transplantation, including anchor methods. Research shows the survival rate of *T. hemprichii* seagrass transplantation has a range of 38.89% to 41.67% [60]. More results were achieved by seagrass transplantation in the range of 90% with the same method but in different seagrass species namely *Enhalus acoroides* [61]. Another method is done by [62], with terfs method obtained 100% success rate. High yields were also reported with the survival of 88.89% to 95% in seagrass transplantation by terfs method [63].

The research was conducted in different locations so that the comparison did not take into account the environmental conditions at the site of each study. Sandy or muddy substrate conditions, light infiltration, and other environmental factors that affect seagrass life also need to be considered. The authors recommend comprehensive research in the successful research of seagrass restoration so that the results obtained can be a reference in seagrass restoration efforts in Indonesia in the future.

3. SEAGRASS RESEARCH DEVELOPMENT IN THE FUTURE

In Indonesia, knowledge of seagrass biology and ecology has increased significantly over the past decade but remains at a relatively low level when compared to the long coastline with the number of scientific publications published. The publication has increased largely in the category of distribution studies and biodiversity of seagrass in each area. Publications in the field of carbon sequestration and seagrass ecosystem relationships with other organisms are also at a good rate when measured in terms of publication quantity, whereas mechanistic and process studies at the individual, genetic, and restoration levels are few.

Seagrass beds in Indonesia have the same important ecosystem functions and services as in other parts of the world, but appear to be experiencing rapid declines in most locations indicated by low bud density, low biomass, and excessive growth of seagrass epiphytes. Long-term studies of seagrass dynamics are still needed to fully understand seagrass dynamics in some areas of Indonesia. Funding for seagrass studies should be encouraged in the future given the many recommendations to protect seagrass in many studies. The role of seagrass ecosystems in providing habitat for

fish and other invertebrates is even to feed on large fauna species such as turtles and dugongs.

Given the great attention to the negative trend of seagrass distribution in Indonesia due to human pressure in coastal zones, future studies will be useful if directed at how to overcome mechanisms that drive changes in seagrass performance and ecosystem changes. Currently, most impact studies are descriptive with a limited focus on cause and effect. Funding for experimental and long-term studies is needed to provide advice for coastal managers to protect seagrasses in particular as local factors and their interactions are considered important for seagrass management and conservation. In the short term, local people's education on seagrass ecosystems can be beneficial in seagrass conservation efforts. Currently, education about seagrass in Indonesia is far behind the coral reef and mangrove ecosystems. By having knowledge of the role of human pressure in seagrass, local people can appreciate this habitat more and thus help protect the remaining seagrass habitats.

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