Chapter 15
Seagrass of Southeast Asia: Challenges, Prospects, and Management Strategies

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15.1 Introduction

The Southeast Asian region, which has a population of 677 million people and accounts for more than 8.5% of the global population, is rich in biodiversity hotspots that are home to a vast diversity of endemic species and unique ecosystems in both terrestrial and marine habitats. The region covers 11 countries with various

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biogeographical niches and culturally distinct inhabitants that rely on the coastal region for their survival. Unlike the attention paid to the coral and mangrove ecosystems, the scientific community has paid less attention to the seagrass ecosystem. This is due to the large-scale ecosystem size of coral and mangrove habitats, as well as the economic and aesthetic values embedded in those ecosystems, as opposed to small-scale ecosystems like seagrass. Despite the fact that they only cover a small portion of the seabed, they have a more significant role in combating ocean acidification, global warming, and greenhouse gas footprints, which in return promote the recruitment of corals after bleaching episodes (Fortes et al. 2018).

Seagrass meadows are a prime example of a habitat that is largely understudied and poorly documented in the Southeast Asian region (Waycott et al. 2009), with only 62 ISI cited seagrass-related publications between the 1980s and 2010 (Ooi et al. 2011), the majority of which are on two specific sites in the Philippines' Northwest Luzon and Indonesia's South Sulawesi. Much of the information on the seagrasses of this region collected in the globally financed initiatives like the UNEP-GEF South China Sea Project (United Nations Environment Programme (UNEP) 2008) lies as grey literature. However, these studies focus only on specific locations, neglecting the larger Southeast Asian region, which is data deficient. Seagrass meadows are well-known for providing a variety of important ecosystem services, including habitat formation, nutrient cycling, carbon sequestration, and food provisioning (Cullen-Unsworth and Unsworth 2013), with many coastal populations in Southeast Asia directly reliant on these habitats for survival (William and Heck Jr. 2001; Masahiro et al. 2014). Seagrasses are also declining at a global rate of about 7% (Waycott et al. 2009). In Southeast Asia, the losses may be more severe due to increased coastal landform transformations and incomplete baseline information seagrasses. The socio-economic-cultural linkages between seagrass meadows and coastal inhabitants, which scholars now recognise, are maybe just as essential (Unsworth and Cullen 2010). Two previous reviews (Fortes 1995; Kirkman and Kirkman 2002) identified sediment circulation, eroded shores, and storms as reasons for seagrass loss in Southeast Asia, and these risks, as well as their accompanying issues, are still relevant today. Instead, this review paper will focus on the current level of knowledge about seagrass in Southeast Asia, with a particular emphasis on the breadth of seagrass within the varied biogeographic regions of the region's marine habitats. Based on the status review, we focus on the areal gaps in knowledge within Southeast Asia, followed by a broader thematic gap analysis. We also address the conservation and management problems posed by these gaps. We offer a comprehensive roadmap for seagrass conservation and study across Southeast Asia to improve the coastal environment's adaptive capability to natural and anthropogenic stressors and so as to help the people who rely on the coastal resources.

15.2 Seagrasses of Southeast Asia

Seagrass meadows are abundant in the tropical seascape, and their distribution relates closely to the habituation of corals and mangroves due to the availability of service agents. It is estimated that seagrass meadows contribute 15% of the ocean carbon storage worldwide and are identified to be the most vulnerable habitat due to exposure to various anthropogenic factors. Furthermore, many important herbivores on coral reefs use seagrass as an alternate grazing habitat; therefore, safeguarding fisheries in seagrass meadows contribute to coral reef fish assemblages' functional purpose. It means that supporting seagrass conservation activities does not compete but instead offers mutualistic support that works hand in hand with coral reef conservation efforts (Fortes et al. 2018).

Six seagrass bioregions span the globe's oceans, including tropical and temperate areas (Short et al. 2007). Southeast Asia is part of the Indo-West Pacific bioregion (Bioregion 5), which spans east Africa to the eastern Pacific Ocean and is known for being the world's largest and most biodiverse region (24 species). According to Fortes (1988)'s cluster study for the Indo-West Pacific seagrasses, Southeast Asia is potentially a separate biogeographic region within the Indo-West Pacific. The Philippines and Brunei Darussalam were also found to be slightly different from other locations due to high seagrass species counts in the former and low species numbers in the latter (Fortes 1988), implying that finer-scale zones within Southeast Asia may exist if distribution data is updated. In Malaysia, 16 species of seagrasses were recorded and distributed along 78 locations in a scattered fashion in coastal waters in peninsular and East Malaysia.

The Sunda Shelf and Western Coral Triangle have the highest species richness (15 species) at the province level. Individual ecoregions within these provinces have species richness ranging from 3 to 14 species (Fig. 15.1), but we omitted *Halophila gaudichaudii* and *Halophila tricostata* from our dataset due to locational uncertainty. The Cocos-Keeling/Christmas Island ecoregion (3 species) and the South China Sea Oceanic Islands ecoregion (3 species) had low species counts (4 species). Both ecoregions, which are made up of atolls with lagoon seagrass meadows, are relatively isolated. Low species richness in these lagoons is likely due to either a narrow dispersal pathway between meadows in Southeast Asia and these remote locations or a lack of acceptable biological drivers for the bulk of species. The number of seagrass species and the size of recognised meadows in Southeast Asian marine bioregions have been well recorded and discussed elsewhere (Fortes et al. 2018) and are shown in Fig. 15.1.

The Malacca Strait emerges as a distinct ecoregion in terms of species richness. It is one of the smaller ecoregions, although it is home to 14 seagrass species. Because it connects the Indian Ocean and the South China Sea, this small strait, spanning 926 km in length, is one of the busiest cargo channels in the world (Ibrahim and Nazery 2007). The placement of the strait in an area of overlap between Indian and the Pacific Ocean fauna was cited as a potential explanation for high species richness in a study of worldwide shore fish biodiversity (Carpenter and Springer 2005). This

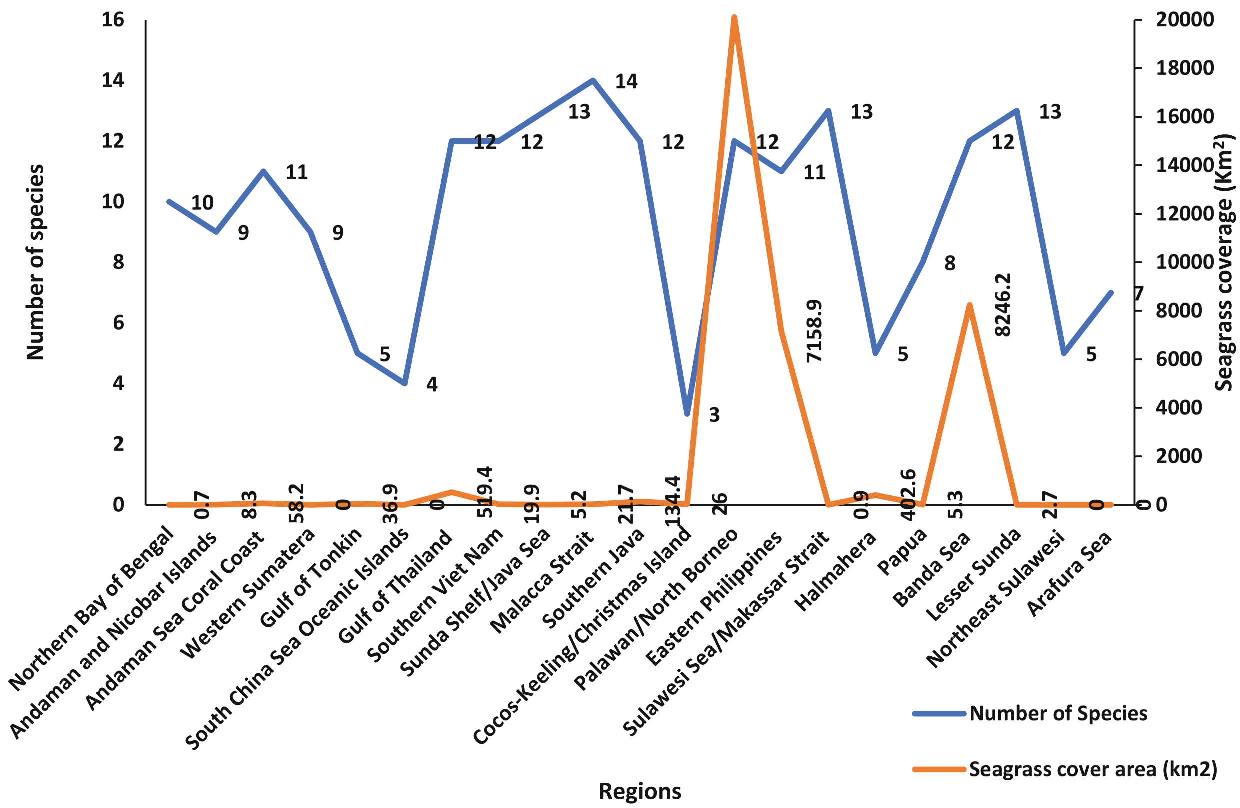

Fig. 15.1 Number of species and respective seagrass coverage area in (km^2) in representative regions are depicted. Value zero (0) in the secondary axis represents the data on seagrass coverage in those regions that are not available in the literature

ecoregion is known as the Indo-Pacific Barrier (Bowen et al. 2016), which is the equivalent of a marine Wallace line that separates populations of marine animals on both sides of the strait due to changes in sea level over glacial times. This knowledge helps guide the selection of sampling locations for seagrass phylogeographic studies that address questions about biodiversity distributions in Southeast Asia and test hypotheses about Southeast Asia as a centre of overlap, refuge, accumulation, or origin for seagrasses, such as those proposed by Mukai (1993) and Nguyen et al. (2013, 2014). However, we believe it is essential to highlight that development in the Malacca Strait due to shipping, port construction, and land reclamation is likely to influence how quickly seagrasses and other marine ecosystems change in the near future (Mokhzani 2004; Ibrahim and Nazery 2007).

Thalassia hemprichii is the most widespread species in Southeast Asia, with distribution records in all ecoregions, including the South China Sea Oceanic Islands. *Cymodocea serrulata* and *Cymodocea rotundata* are also frequent species, except for the South China Sea Oceanic Islands and the Cocos-Keeling/Christmas Islands, which exist in all ecoregions. *Halophila sulawesii* (Kuo 2007), with only one record on Samalona Island in the Spermonde archipelago (see also: Taxonomic Highlights, below), and *Zostera japonica* in the Gulf of Tonkin were two species that were unique to one ecoregion (Luong et al. 2012).

Seagrass meadows cover 36,762.6 km^2 in Southeast Asia, accounting for around 0.8% and 24% of the total area, respectively, compared to the entire landmass and coastline length. Palawan/North Borneo (20,115 km^2), the Eastern Philippines (7159 km^2), and the Banda Sea (8246.2 km^2) ecoregions, all of which are part of the Western Coral Triangle Province, have the most prominent areas. In terms of seagrass meadow estimates, not all ecoregions are equally well-represented. The Oceanic Islands of the South China Sea, Western Sumatera, Northeast Sulawesi, and the Arafura Sea ecoregions, for example, all have significant data gaps. These will be emphasised in greater detail in the section 'Real knowledge and information shortages'.

15.3 Taxonomic Uncertainty

There are 21 species of seagrasses in Southeast Asia, but some are still considered taxonomically questionable. *Halophila* is the genus with the most significant number of unvalidated species. Although this genus has a lot of taxonomic diversity, its constituent species seem to have overlapped leaf morphologies, making confirmation difficult. The species' plasticity in response to varied substratum, salinity, and light regimes has been studied (Japar Sidik et al. 2010). This is the main reason for taxonomic ambiguity based only on morphological features.

Halophila major has been investigated more thoroughly throughout Southeast Asia than other species in its genus, using a combination of morphological and molecular features. As a result, it has recently been recorded in Indonesia, Thailand (Tuntiprapas et al. 2015), Malaysia, Myanmar, Viet Nam, and the Philippines (Nguyen et al. 2013, 2014). Despite being recognised as two different species by

Kuo, *Halophila minor* and *Halophila ovata* were treated as synonyms for the seagrass flora of Singapore (Yaakub et al. 2013). Kuo (2000) offered *Halophila gaudichaudii* as a replacement for *H. ovata*, which was later deemed an illegitimate name (2006). As a result, all three confounding species, *H. minor, H. ovata, and H. gaudichaudii*, are found in this region's species records and are described in this review to maintain the transparency of these species listings until a taxonomic consensus is reached. However, *H. major* was found in records from Vietnam (Southern Viet Nam ecoregion) and Myanmar (Northern Bay of Bengal ecoregion); *H. gaudichaudii* was found in recordings from the Andaman and Nicobar Islands and the Philippines; and *H. ovata* was found in records from the Philippines (ecoregion undetermined). *Halophila tricostata* is native to Australia's east coast. Its presence in Southeast Asian species records suggests that it has the potential for long-distance migration from Australia's Great Barrier Reef to the Palawan/North Borneo ecoregion.

15.4 Fishes Are in Preference of Seagrass Ecosystem

Without a doubt, the seagrass ecosystem benefits the fishing industry by offering more suitable fishing grounds. Fishers will have to hunt elsewhere for resources when alternative dominating taxa replace hard corals (e.g., soft corals, corallimorphs, and sponges) and reef accretion declines. Seagrass ecosystems are an example of an alternative fisheries habitat that provides broad shallow-water fishing grounds that are often easily accessible (Murugan et al. 2014; Nordlund et al. 2018). When these seagrass systems are robust, they include an abundance of productive fish and invertebrate fauna (Al-Asif et al. 2020). Even with modest gear, it is often easy to catch fish and invertebrates in seagrass meadows. Seagrass meadows can host very productive fish assemblages of significant commercial and subsidence importance when healthy and effectively managed.

There is extensive evidence of high-intensity seagrass fishing efforts in Indonesia and the Philippines. Many of these sites have become severely deteriorated reefs. Fishermen target seagrass meadows in Indonesia where reef fisheries are fast declining (Unsworth et al. 2015). There is also evidence that fishers are rapidly working their way down the food chain, becoming more reliant on species that were originally thought to be highly unattractive, indicating unsustainable demand on the available seagrass resources (Abu Hena et al. 2015; Johan et al. 2020). In the Philippines, similar patterns have been seen. Seagrasses, as opposed to mangroves and coral reefs, have been proven to be the most visited fishing grounds in the Indo-Pacific region, delivering the most community benefits (Unsworth 2010). The growing reliance on seagrass meadows as a primary fisheries habitat has led to the widespread employment of ever more efficient and exploitative fishing tactics, such as static fish fences (Unsworth et al. 2015), which has resulted in increased food chain damage.

15.5 Feasibility in Seagrass Conservation

Tropical seagrass meadows receive very little conservation money, and seagrass research is minimal compared to other ecosystems like coral reefs and mangroves. Furthermore, the administration and management of seagrass ecosystems are almost non-existent in many regions of the planet.

Local and regional consequences such as deteriorated water quality, physical disturbance, and the collapse of food webs are putting a strain on seagrass meadows (Waycott et al. 2009; Unsworth et al. 2019). Seagrass decline has been rapid and widespread worldwide (Unsworth et al. 2019). The causes of seagrass loss, on the other hand, are mainly controllable, and dangers can be mitigated with targeted measures (Cullen-Unsworth and Unsworth 2016). Seagrass restoration is becoming more successful (Sudo et al. 2021), and a growing number of catchment management examples lead to long-term seagrass recovery. Although seagrass restoration is costly, and many major projects have failed in the past, there has been a significant shift in the tactics adopted in the last decade. As a result, there are now many successful projects carried out at a reasonable cost (Sudo et al. 2021). This includes recent multi-species tropical seagrass restoration, and in some conditions, restoration can now be done extremely cheaply by large-scale seed distribution (Sudo et al. 2021). Regardless, preserving extensive productive seagrass meadows rather than rebuilding or recreating them is the most efficient and viable conservation technique.

Seagrass protection must be addressed not only to boost seagrass viability, but also to prepare for fishermen's rising reliance on these areas. It is no longer adequate for marine protected area management plans to incorporate seagrass management as a 'check box exercise', if at all; rather, seagrass management must be intentionally included using best-practice science to increase fisheries productivity. The main challenge for coastal ecosystems in many parts of the world is watershed degradation (e.g., loss of river vegetation and deforestation). Therefore seagrass protection does not necessarily have to be the priority. Ridge-to-reef conservation programs can address more significant concerns like catchment degradation and poor water quality and serve as a platform for larger initiatives like seagrass protection.

15.6 Knowledge Gaps

Seagrass information in Southeast Asia is imbalanced spatially, with hotspots and cold spots of research activity. The degree of information varies within hotspots, with some reporting only species occurrence and others reporting both species presence and meadow size estimates. Because of the logistical challenges of mapping seagrass meadows, estimates of meadow size are rarely addressed. As a result of advancements in remote sensing technology and well-funded regional projects like the UNEP/GEF South China Sea Project (United Nations Environment Programme (UNEP) 2008), the Bay of Bengal Large Marine Ecosystem Project in which Myanmar represents from Southeast Asia (BOBLME 2015), and the JSPS-Asian CORE Project, areal estimates for seagrass meadows have only recently begun to emerge more rapidly. Meadow size data are essential for moving seagrass conservation and management forward in the region because they provide baselines for understanding ecosystem trajectories, either under natural conditions or in response to long-term environmental change, as in the case of Waycott et al. (2009)'s global analysis of seagrass trajectories.

To some extent, access to seagrass sites affects the distribution of data points in the region. Researchers cannot access remote locations because of distance, or the location itself lies within a conflict territory. The Spratly Islands are part of the South China Sea Oceanic Islands, which have been the subject of several overlapping maritime claims by the Philippines, Malaysia, Vietnam, Brunei, Taiwan, and the People's Republic of China for more than 50 years. These sites are natural laboratories for testing hypotheses concerning allopatric differentiation in seagrass and seagrass-associated species and elucidating seagrass dispersal routes in the region due to their physical isolation. In the case of coral reef fish larvae from the Spratly Islands, larval drift time and vector current charts show that the western Philippines, Taiwan, south-eastern China, Brunei, and Malaysia are natural sink habitats (McManus 2017). Long-distance dispersal has also been demonstrated in seagrasses using seeds, fruits, viviparous seedlings, and vegetative fragments, all of which can travel hundreds of kilometres (Kendrick et al. 2012). However, because of the quantity of recent island-building in this ecoregion as a result of aggressive territorial claims, urgent work is required if seagrass scientists in the region want to fill in this data gap (Southerland 2016). Sand dredging and land reclamation are frequently used in the construction of islands on shallow coral reefs and lagoons. Two-thirds of currently occupied atolls in the Spradley's have been demonstrated to have proportionally smaller reef extent than uninhabited atolls, showing that island-building has a negative impact on reef systems (Asner et al. 2017). Seagrasses, like these reefs, maybe similarly harmed before being documented and examined for research.

Despite the ongoing increase in research, it is clear that much work remains to be done in order to close the gaps in knowledge and information. There is almost minimal social science study on the social, cultural, and economic elements of human–seagrass interactions, for example, and there is emerging research that indicates critical linkages between coastal communities and seagrass beds (Cullen-Unsworth et al. 2014). Furthermore, while the importance of seagrass fisheries activity has been recognised internationally (Nordlund et al. 2017), there is a data gap in the Southeast Asian region regarding seagrass fishing resources and the flow-on benefits from ecological services it provides (Unsworth 2010).

15.7 Future Challenges

A number of challenges were extensively discussed to achieve better management of seagrass ecosystem. They are

1. Lack of trained researchers
2. Limited scope of work
3. Knowledge gaps
4. Misguided management efforts
5. Lack of implementation and enforcement of environmental laws
6. Socio-economic and cultural disconnect

The first three issues revolve around the absence of knowledge, competence, and information as fundamental issues. Collaborations and partnerships with research partners from outside the region have helped the region develop expertise in seagrass research and information on tropical seagrass environments. The region's actual capacity building and training of researchers appeared to be concentrated in a few institutions, with little to no information sharing outside of those institutions. Seagrass research conducted by researchers outside of centres of knowledge tends to be extremely descriptive, which is likely due to a lack of training, experience, and resources. This lack of information and training, particularly in basic procedures, exacerbates the absence of basic understanding about seagrass meadows in Southeast Asia, resulting in a scarcity of basic data like as spatial extent, species composition, and cover. To overcome these obstacles, a systematic and multi-pronged strategy is required, and it must originate from scholars stationed in Southeast Asia. Forming a (even if informal) network of scientists operating in the region fosters collaborative and supportive research and knowledge sharing. Workshops for young researchers should be promoted, as should inter-institutional collaboration and exchanges. Knowledge sharing can also help researchers avoid duplication of effort and resource and equipment sharing, and institutional diversity can help researchers compete for funding.

The following three difficulties concern policymaking and natural resource management. While management efforts have been launched at a number of locations around the region, they have generally focused on remedial or curative measures rather than addressing the underlying issues. Many of the causes of seagrass decrease in Southeast Asia have been extensively documented, and many of them may be traced back to anthropogenic pressures such as coastal development. To prevent continued degradation of seagrass meadows throughout the region, these issues must be addressed. Although seagrass relocation and restoration are periodically attempted, they are frequently not the most cost-effective alternative because success rates are low despite a substantial investment of time and money (Van Katwijk et al. 2015). Ineffective solutions are often exacerbated by a lack of effective links between science, government, and the commercial sector, resulting in poor management and conservation measures. There is a significant divergence between seagrass science, policy, and practice at the moment.

One of the most difficult aspects of enforcing environmental rules is dealing with opposition from local maritime communities (Bennett and Dearden 2014). The last major obstacle to seagrass protection is the social, economic, and cultural divide. TeamSeaGrass is a member of the Seagrass-Watch Network, and the information gathered by volunteers has been used in scientific papers (Yaakub et al. 2014; McKenzie et al. 2016), as well as shared with management from Singapore's National Parks Board (NParks).

15.8 Conclusion

Humanity cannot afford to let another marine ecosystem's integrity be jeopardised due to poor stewardship of our planet's resources. It is crucial to maintain essential ecosystem services. The moment has come for large conservation donors, government regulators, and conservation stakeholders to refocus their efforts on where ecosystem services will be needed now and in the future. Indeed, there is mounting evidence that global fisheries management regimes must adjust to changing climate conditions and adopt adaptive policy aims. It's also crucial to think about which conservation projects could benefit multiple aspects of the seascape, even if they aren't the most effective approach for one habitat in particular. Reducing land-based pollution, for example, will benefit seagrass meadows and coral reefs, as well as other nearby habitats. As a result, it's critical to analyse and argue for the seascape's overall benefits. Depending on the in-water circumstances, enhancing water quality may be the most significant activity for seagrass, and it would also benefit other systems. Importantly, we must prioritise ecosystem-related measures that promote ecosystem services. Some 'bright spots' in coral reef protection show the possibility of some coral reef survival. However, for our tropical seas to continue to feed fisheries and people, we must focus on maintaining ecosystems and species that provide the most vital ecosystem services while also being able to withstand future climate change. Seagrass meadows are one of these ecosystems, and preserving them is critical for the lives and food security of hundreds of millions of people. Seagrass ecosystems are in desperate need of protection, and now is the high time to act.

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