Preface

It has been commonly accepted that biological diversity is important as a natural resource and for the functioning of the ecosystem that provides us with benefits essential for human well-being. However, biodiversity loss is continuing on both regional and global scales. To change this trend, the Convention on Biological Diversity at COP10 has adopted the new Strategic Plan for Biodiversity, including the Aichi Biodiversity Targets for the 2011–2020 period. Among the Aichi Biodiversity Targets, no. 19 states, "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied." To achieve this target, promotion of biodiversity observations including development of new technologies is needed.

In March 2012, to provide a quantum step forward in advancing science that optimizes the synergy between development and biodiversity conservation in Asia, we published the book *The Biodiversity Observation Network in the Asia-Pacific Region: Toward Further Development of Monitoring*. In that book, we provided an overview of biodiversity observation studies now organized under the Asia-Pacific Biodiversity Observation Network (AP-BON).

Here, we are publishing the second volume from AP-BON and have decided to launch a new book series titled *Asia-Pacific Biodiversity Observation Network* as a subseries in Ecological Research Monographs. Using this series, we will advance knowledge, the science base, and technology relating to biodiversity of the Asia-Pacific Region and thereby contribute to the achievement of the Aichi Biodiversity Targets by 2020.

In the present book, we have collected papers that review the challenges of studying the spatial variability of biodiversity and ecosystems in the Asia-Pacific region. A special focus is on reviews of advances in concepts and methods of biodiversity observation including ubiquitous genotyping, systematic conservation, monitoring of the function and services of ecosystems, and biodiversity informatics. Together with newly developed concepts and methodologies, the contributions of the present book will lead to the establishment of integrative observations and assessments of Asian biodiversity, which are unquestionably required for reporting the status of biodiversity in this region and for contributing to its effective conservation and sustainable use.

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Chapter 20
Regional Comparison of the Ecosystem Services from Seagrass Beds in Asia

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Abstract Coastal ecosystems offer valuable services to human society. However, these ecosystems are facing multiple impacts of human-induced stress, including overexploitation, eutrophication, land construction, and global climate change. The prediction of long-term changes in coastal ecosystems under multiple impacts is difficult because nonlinear and cumulative effects operate simultaneously. This difficulty is especially true for Asian regions, where coastal biodiversity is the world's highest but the least studied. In this chapter, we compare ecosystem services of coastal areas of Asia based on the expert knowledge of practioners who study coastal ecosystems at each locality. We especially focused on seagrass beds, which provide important services to humans including provision of seafood

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and regulation of water conditions. We selected the six most important ecosystem services at each of 13 seagrass beds ranging from Japan to India and evaluated the direction of changes over the past two decades. We also evaluated public awareness and data certainty for each service. Food provisioning, water purification and waste treatment, erosion regulation, recreation and ecotourism, and educational values were selected as major ecosystem services of seagrass beds. Degradation during the over past 10–20 years was reported for most provisioning and regulating services, whereas improving trend was found for cultural services in most sites. Public awareness and certainty of information were generally high for provisioning services, but low for most regulating services. Regional variation along latitude, and differences between temperate and tropical seagrass beds, were not detected for the examined variables. Regional comparisons of ecosystem services shed light on general and specific aspects of the status of seagrass beds, which will provide baseline data for planning effective conservation and management strategies under multiple human impacts.

Keywords Asia • Data certainty • Ecosystem service • Expert knowledge • Multivariate analysis • Public awareness • Seagrass bed • Temporal change

Introduction

Coastal ecosystems worldwide, such as coral reefs, mangrove forests, seagrass meadows, and algal beds, provide valuable ecosystem services and form highly productive zones in an otherwise barren ocean. For example, the net primary production of coastal ecosystems accounts for approximately 25 % of that of the entire marine ecosystem, despite occupying a mere 9 % of the world's oceans (Duarte and Cebrián 1996). The net primary production from aquatic vegetation such as seagrass and salt marsh habitats is comparable to that of tropical and temperate rainforests (Whittakar 1975; Duarte and Chiscano 1999). Coastal habitats such as coral reefs, seagrass beds, and mangrove forests are also effective habitats and nurseries because their three-dimensional structure supports numerous

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flora and fauna, including endangered (Kikuchi and Perès 1977; Williams and Heck Jr 2001; Nakaoka 2005) and commercially important (Heck et al. 2003) species. These coastal habitats also have important roles in the cycling of nutrient and organic matter, through processes such as decomposition and accumulation, thus regulating water quality and sediment dynamics in these areas (Marbà et al. 2006).

The many functions of coastal ecosystems provide valuable services to human society, of which provision of seafood and regulation of water quality are two of the best known (Constanza et al. 1997; McArthur and Boland 2006; Unsworth and Cullen 2010). The economic valuation of regulatory services for water quality and nutrient cycling provided by coastal ecosystems such as salt marshes, mangroves, seagrass beds, and algal beds alone are estimated to be ten times that of major terrestrial ecosystems per unit area (Constanza et al. 1997). Furthermore, these values are almost certainly an underestimate in light of recent studies that highlight the importance of coastal ecosystems in their roles of climate regulation through carbon sequestration (Nellemann et al. 2009; Fourquean et al. 2012) and disaster prevention against natural disturbances such as typhoons and tsunamis (Adger et al. 2005; Chatenoux and Peduzzi 2007; Whanpetch et al. 2010). The increased recognition from the scientific and research community on the importance of coastal ecosystems and the vital services they provide makes them ideal examples for environmental education and for generating public awareness on environmental issues (Huang et al. 2006; Fortes et al. 2007; Abu Hena and Ashraful 2009).

The last century has seen, worldwide, a rapid deterioration of key coastal habitats and the valuable ecosystem services they provide, largely as a result of multiple human-induced impacts such as overexploitation, eutrophication, land construction, and global climate changes (Steneck and Carlton 2001; Harley et al. 2006). For example, since 1990, the majority of tropical reef systems are experiencing a decrease in live coral cover at rates of 1–9 % year^{-1} (Gardner et al. 2003; Bellwood et al. 2004), mangrove forests are declining at an estimated rate of 2 % year^{-1} (Valiela et al. 2001), and seagrass beds are disappearing at a rate of 7 % year^{-1} globally (Waycott et al. 2009). In most cases, the estimates were based on data collected in developed Western countries with limited input from significant coastal regions such as Asia, where a large percentage of the populations reside in coastal areas and are directly dependent on its resources. Asia, and Southeast Asia in particular, is the region with the highest concentration of marine biodiversity in the world, and it is possible that the estimated rates of decline are in fact underestimated because of a dearth of long-term quantitative scientific data from the region (Spalding et al. 2001, 2010; Green and Short 2003). This possibility brings to light the urgent need for systematic studies in Asian coastal areas to understand the status of habitats and ecosystem services, and to promote active and informed decision making and management for the conservation of marine biodiversity and sustainable use of marine resources.

A cost-effective approach in understanding the status of coastal systems where quantitative scientific data are lacking is to carry out comparative analyses based on the knowledge of experts in each locality, especially when analyzing ecosystem services for parameters such as cultural services for which quantitative data are difficult to obtain. Among different coastal habitats in Asia, seagrass beds are suitable for broad-scale comparative studies because they occur widely along the whole Asian coast, from tropical regions to the temperate and subarctic seas along the northwestern Pacific (Green and Short 2003). The network of Asian seagrass researchers has also been developed through some key international organizations and programs such as World Seagrass Association (http://wsa.seagrassonline.org), SeagrassNet (http://www.seagrassnet.org), Seagrass Watch (http://www.seagrasswatch.org), and Census of Marine Life (http://www.coml.org), which has given seagrass scientists and managers the capacity and opportunity to carry out a cross-site comparison over broad spatial scales.

The aim of this chapter is to analyze the current status of some key seagrass beds in Asia using a unified protocol focused on changes in ecosystem services of seagrass beds during the past 20 years. We analyzed inputs from local seagrass experts to identify regional variations in important ecosystem services, the direction of changes, public awareness, and data certainty. The results from this study will be used as baseline data to aid in understanding coastal marine biodiversity and in forming effective management strategies for coastal resources in Asia.

Methods

Study Sites

We targeted 13 seagrass beds from ten Asian countries spanning both temperate (Japan, Korea, north China) and tropical (south China, Philippines, Indonesia, Singapore, Malaysia, Thailand, Bangladesh, India) seagrass beds (Fig. 20.1). One to two sites were chosen from each country to avoid skews in the distribution of sites, which may cause bias in analyses. For the same reasons, each expert report (coauthors of this paper) was confined to one site, except for the Philippines where two experts cooperated to report on one site. All sites selected have been observed and/or studied by each expert and his/her colleagues over the long term (10–20 years or more), and information on temporal changes is available either quantitatively or qualitatively.

To avoid mismatches in scale of the sites selected, we defined the spatial extent of seagrass beds hierarchically according to three categories: (1) region: the area defined at extent of ~20–100 km in scale; (2) local: the area defined at extent of ~5–20 km in scale; and (3) meadow: the area defined at <5 km in scale. As a result, each site is represented either by one large seagrass bed or several moderate to relatively small seagrass beds. An exception to this rule is Singapore where six very small seagrass beds scattered over a distance of 40 km were treated as a group because the ecosystem services for these small meadows were similar to each other. Approximate seagrass bed size and seagrass species composition were described for each site.

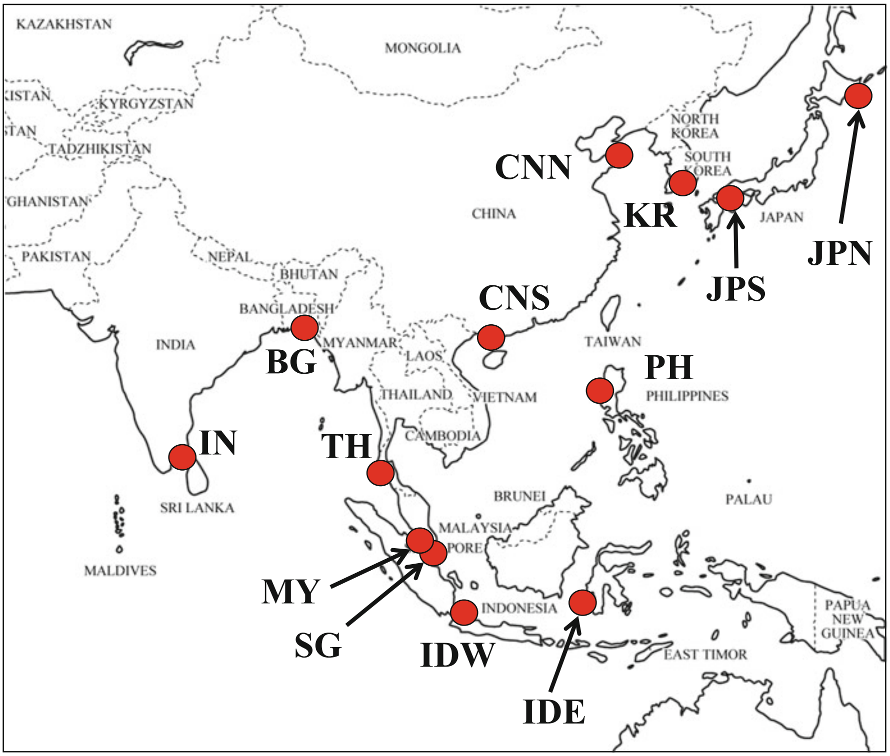

Fig. 20.1 Location of 13 study sites in Asia. See Table 20.2 for the site codes

Evaluation of Ecosystem Services

Each expert selected six ecosystem services that he/she determined was most important to that site. The selection was based on the criteria given by the Millennium Ecosystem Assessment (2003) (Table 20.1). We used categories in the provisioning, regulating, and cultural services, but did not include supporting services because they were indirect services and overlapped with three other types of services. Some categories were not relevant to marine ecosystems (e.g. freshwater supply, air quality regulation, water regulation, and pollination) and these were excluded from the list.

For each selected ecosystem service, we evaluated the direction of change based on the three categories: (1) improving; (2) degrading, and (3) no change. The temporal scale was set to track changes that occurred over the past 20 years (from the 1990s to early 2010s). We also scored public awareness of each ecosystem service by assigning a rank according to the perceived degree of awareness of the ecosystem services provided as follows: (1) high: public is keenly aware; (2) medium: informed scientists, managers, and/or leaders are aware; and (3) low: seldom considered in decision making, low awareness within local community.

Table 20.1 Classification of ecosystem services and their description based on Millennium Ecosystem Assessment (2003)

Types of ecosystem services	Description
Provisioning services	
Food	Includes the vast range of food products derived from plants, animals, and microbes
Fiber	Materials included here are wood, jute, cotton, hemp, silk, and wool
Fuel	Wood, dung, and other biological materials serve as sources of energy
Genetic resources	Includes the genes and genetic information used for animal and plant breeding and biotechnology
Biochemicals and medicines	Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems
Ornamental resources	Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments
Regulating services	
Climate regulation	Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases
Erosion regulation	Vegetative cover plays an important role in soil retention and the prevention of landslides
Water purification and waste treatment	Ecosystems can be a source of impurities (for instance, in freshwater) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes
Disease regulation	Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes
Pest regulation	Ecosystem changes affect the prevalence of crop and livestock pests and diseases
Natural hazard regulation	The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes and large waves
Cultural services	
Cultural diversity	The diversity of ecosystems is one factor influencing the diversity of cultures
Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components
Knowledge systems	Ecosystems influence the types of knowledge systems developed by different cultures
Educational values	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies
Inspiration	Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising

(continued)

Table 20.1 (continued)

Types of ecosystem services	Description
Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations
Social relations	Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies
Sense of place	Many people value the sense of place that is associated with recognized features of their environment, including aspects of the ecosystem
Cultural heritage values	Many societies place high value on the maintenance of either historically important landscapes (cultural landscapes) or culturally significant species
Recreation and ecotourism	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area

Finally, the certainty of the information provided was classified according to three ranks: (1) high: quantitative data available showing the change, and/or qualitative but reliable data available from literature; (2) moderate: no quantitative data or literature available, but each expert is quite certain about the change based on his/her own observation and/or through personal communication from colleagues and local community; and (3) low: little information available, but an expert could speculate the direction of changes based on his/her experience and previous knowledge, such as through case studies at other sites under similar conditions.

Data Analyses

In addition to qualitative comparisons of obtained data, the following univariate and multivariate statistical analyses were conducted on site information and ecosystem service evaluation.

Variation with latitude in seagrass bed area and seagrass species richness was tested by Spearman's rank correlation.

Status of ecosystem services was represented by the four multivariate parameters: (1) Top Six Ecosystem Services, (2) Direction of Change, (3) Public Awareness, and (4) Data Certainty. Dissimilarity in these parameters among the 13 sites was analyzed using the Bray–Curtis index. For ecosystem service selection, the presence/absence data on each service were used to calculate the dissimilarity. For the latter three parameters, a rank score between 1 and 3 was given, where 1 indicates degradation and 3 indicates improvement for the direction of change parameter, whereas 1 indicates low and 3 high for both public awareness and the data certainty parameters. For the ranked data, the average value for each of the three categories of ecosystem services (provisioning, regulating, and cultural) was then obtained and used to calculate the dissimilarity between all pairs of sites. Variation in dissimilarity was graphed using a nonmetric Multidimensional Scaling (nMDS) ordination method based on 20 iterations of data (Clarke and Warwick 2001).

To test if the patterns of these variables on ecosystem services vary between temperate (four sites in Japan, Korea, and Northern China) and tropical (nine sites) seagrass beds, one-way PERMANOVA (Anderson 2001) was carried out using the statistical software R with "vegan" packages (Oksanen et al. 2012; R Development Core Team 2012). Finally, the correlation among four dissimilarity matrices on ecosystem service properties was tested using the Mantel test based on 999 permutations. The correlation between each dissimilarity matrix and three accountable variables was also analyzed to test if the similarity in ecosystem service status is related to these factors. The three variables aforementioned are (1) the geographic distance between the sites; (2) the difference in latitude between sites; and (3) the dissimilarity in seagrass species composition (taken from the Bray–Curtis index on the presence/absence data).

Results

The 13 seagrass beds selected for the comparative analyses varied greatly in geography and latitude (Fig. 20.1, Table 20.2). The area of seagrass differed by more than 400 fold between the largest one at the Gulf of Manner in India and the smallest at Bakkhali Estuary in Bangladesh (Table 20.2), but there was no significant correlation between bed size and latitude (Spearman's rank correlation: $\rho = 0.242$, $p = 0.425$). Species richness of seagrass beds varied from a minimum of 1 species in Bakkhali Estuary (Bangladesh) to a maximum of 12 species in Singapore and India (Table 20.3). Seagrass species richness was negatively correlated with latitude ($\rho = -0.738$, $p = 0.004$).

Seagrass beds at the four northern sites were dominated by species belonging to Zosteraceae, whereas those in the tropics were dominated by species belonging to Hydrocharitaceae and Cymodoceaceae (Table 20.3). Some species such as *Zostera japonica*, *Halophila ovalis*, and *Ruppia maritima* were found in both regions.

Selection of Important Ecosystem Services

Many experts overlapped in their selection of the most important ecosystem services for their respective sites (Table 20.4). Food provisioning was selected at all sites, whereas other categories in provisioning services were not selected with the exception of genetic resources, biochemical, natural medicine, and pharmaceuticals in some sites.

For regulating services, many experts selected water purification and waste treatment, which are related to the role that seagrasses play in nutrient cycling.

Table 20.2 Summary of information of studied seagrass beds

Country	Site code	Region Extent of ~20–100 km	Local Extent of ~5–20 km	Meadow Extent of <5 km	Latitude	Longitude
Japan North	JPN	Eastern Hokkaido	Akkeshi	Akkeshi-ko Estuary	43.06°N	144.90°E
Japan West	JPW	Western Seto Inland Sea	Aki-wan	Ikunoshima Estuary	34.30°N	132.91°E
Southern Korea	KR	Southern coast of Korea	Koje Island	Koje Bay	34.82°N	128.58°E
China North	CNN	West Coast of Yellow Sea	Shandong Province	Yuehu (Swan Lake)	37.35°N	122.57°E
China South	CNS	Southern coast of China	Guangxi	Hepu	21.52°N	109.59°E
Philippines	PH	Northern Luzon	Province of Pangasinan	Bolinao Seagrass Demonstration Site	16.42°N	119.95°E
Indonesia East	IDE	South Sulawesi	Spermonde Archipelago	Barrang Lompo Island	5.04°S	119.33°E
Indonesia West	IDW	West Java	Serang	Banten Bay	6.00°S	106.14°E
Singapore	SG	Singapore	Singapore	Singapore	1.28°N	103.79°E
Malaysia	MY	Southwest Johore	Merambong-Tg. Adang	Sg. Pulai Estuary	1.34°N	103.57°E
Thailand	TH	SW Andaman Sea Coast	Trang	Laem Yong Lam	7.38°N	99.33°E
Bangladesh	BG	Eastern Bangladesh	Cox's Bazar	Bakkhali Estuary	21.47°N	91.97°E
India	IN	Southern India	Palk Strait	Gulf of Mannar	9.48°N	78.92°E

Other regulating services that were considered important at several sites include erosion regulation, climate regulation, and natural hazard regulation.

Among cultural services, two categories—educational values, and recreation and ecotourism—were selected at almost all sites, whereas other components such as cultural diversity, spiritual and religious values, inspiration, and aesthetic value were selected in one to three sites.

Variation in the patterns of selection of important ecosystem services among the 13 sites (represented by the dissimilarity index) did not show any tendencies among regions. The selection of ecosystem services was identical for Singapore and Koje Bay (Korea); for Barrang Lompo Island (Eastern Indonesia) and Bakkhali Estuary (Bangladesh); and for Akkeshi-ko Estuary (Northern Japan) and Banten Bay (Western Indonesia) (Fig. 20.2a). The difference in dissimilarity of ecosystem services was not significant between temperate and tropical seagrass beds [permutational multivariate analysis of variance (PERMANOVA): *df* 1, 11; $F = 1.176$, $p = 0.364$]. The variation in dissimilarity of ecosystem services was also not significantly correlated with either geographical distance, latitude, or seagrass species composition (Table 20.5).

Table 20.3 Species richness and species composition of seagrasses in the study sites

Site code	Site name	Area of seagrass beds (km^2)	Species richness	Species composition																				References
				Zm	*Zcae*	*Zcau*	*Zj*	*Hu*	*Hp*	*Cr*	*Cs*	*Si*	*Tc*	*Ea*	*Th*	*Ho*	*Hm*	*Hg*	*Hd*	*Hst*	*Hb*	*Hsp*	*Rm*	
JPN	Akkeshi-ko estuary	12.0	3	+			+																+	Nakaoka et al., unpublished data
JPW	Ikunoshima Estuary	0.5	3	+			+									+								Hori et al., unpublished data
KR	Koje Bay	3.0	4	+	+	+	+																	Lee et al. (2005), Park et al. (2011)
CNN	Yuehu (Swan Lake)	2.5	2	+			+																	Zhang et al., unpublished data
CNS	Hepu	5.4	4				+	+								+					+			Huang et al. (2006)
PH	Bolinao Seagrass Demonstration Site	34.0	9					+	+	+	+	+		+	+	+		+					+	Fortes et al., unpublished data
IDE	Barrang Lompo Island	0.5	6					+		+		+		+	+	+								Sterrenburg et al. (1995), Ambo-Rappe (2010), Amran (2010)
IDW	Banten Bay	3.6	7					+		+	+	+		+	+	+								Douven et al. (2003)
SG	Singapore	0.3	12					+	+	+	+	+		+	+	+	+		+		+	+		Yaakub, unpublished data
MY	Sg. Pulai Estuary	1.1	10					+	+	+	+	+		+	+	+	+					+		Japar Sidik et al. (1996, 2000), Japar Sidik and Muta Harah (2003)

TH	Laem Yong Lam	10.7	10	+	+	+	+	+		+	+	+	+		+			Prathep et al., unpublished data
BG	Bakkhali Estuary	0.2	1														+	Abu Hena et al. (2007), Rezaul (2008)
IN	Gulf of Mannar	85.5	12	+	+	+	+	+	+	+	+	+	+		+	+		Manikandan et al. (2011)

Zm, Zostera marina; Zcae, Zostera caespitosa; Zcau, Zostera caulescens; Zj, Zostera japonica; Hu, Halodule univervis; Hp, Halodule pinifolia; Cr, Cymodocea rotundata; Cs, Cymodocea serrulata; Si, Syringodium isoetifolium; Tc, Thalassodendron ciliatum; Ea, Enhalus acoroides; Th, Thalassia hemprichii; Ho, Halophila ovalis; Hm, Halophila minor; Hg, Halophila gaudichaudii; Hd, Halophila decipiens; Hst, Halophila stipulacea;, Hb, Halophila beccarii; Hsp, Halophila spinulosa; Rm, Ruppia maritina

Table 20.4 Summary of the selection of important ecosystem services and the direction of their changes

Types of ecosystem services	JPN	JPW	KR	CNN	CNS	PH	IDE	IDW	SG	MY	TH	BG	IN
Provisioning services													
Food	Improving	Degrading	Degrading	Improving	Degrading	Degrading	Degrading	Degrading	Degrading	Degrading	Degrading	Improving	Improving
Genetic resources	–	–	–	–	Degrading	–	–	–	–	Degrading	–	–	Improving
Biochemicals and medicines	–	Degrading	–	–	–	–	–	–	–	Degrading	–	–	–
Regulating services													
Climate regulation	Degrading	–	–	–	–	Degrading	–	Degrading	–	–	–	–	Degrading
Erosion regulation	Degrading	–	Degrading	–	–	Degrading	Improving	Degrading	Degrading	Degrading	No Change	Degrading	–
Water purification and waste treatment	Degrading	Improving	Degrading	Improving	Degrading	–	Degrading	Degrading	Degrading	Degrading	Degrading	Degrading	Degrading
Natural hazard regulation	–	–	–	Improving	Degrading	Degrading	Degrading	–	–	–	–	Degrading	Improving
Cultural services													
Cultural diversity	–	Degrading	–	–	–	–	–	–	–	–	–	–	–
Spiritual and religious values	–	–	–	–	–	–	–	–	–	–	No Change	–	–
Educational values	Improving	Improving	Improving	Improving	Improving	Improving	Improving	Improving	Improving	Degrading	Improving	Improving	–
Inspiration	–	–	–	–	–	–	–	–	–	–	Improving	–	–
Aesthetic values	–	–	Improving	Improving	–	–	–	–	Improving	–	–	–	–
Recreation and ecotourism	Improving	Improving	Improving	Improving	Improving	Improving	Degrading	Degrading	Improving	–	–	Degrading	Improving
References	(1–4)	(5–9)	(10–12)	(13–14)	(15)	(16–18)	(19–20)	(21–26)	(27–29)	(30–39)	(40–41)	(42–44)	(45–47)

(1) Hokkaido Prefecture (1991–2009), (2) Iizumi et al. (1995), (3) Hokkaido Enironmental Science Center (2005), (4) Mukai (2005), (5) Hori (2006), (6) Innami (2006), (7) Hori et al. (2007), (8) Yoshida et al. (2010), (9) Hori (2011), (10) Kang et al. (2000), (11) Yoon et al. (2009), (12) Park et al. (2011), (13) Jia et al. (2003), (14) Liu et al. (2011), (15) Huang et al. (2006), (16) Fortes et al. (2007), (17) Holmer et al. (2002), (18) San Diego-McGlone et al. (2008), (19) Erftemeijer and Allen (1993), (20) Ambo-Rappe (2010), (21) Douven (1999), (22) Douven et al. (2003), (23) Glimmerveen (2001), (24) Kiswara (2009), (25) Lindeboom et al. (2000), (26) Tiwi (1999), (27) Loo et al. (1996), (28) Low and Chou (1994), (29) Davison et al. (2008), (30) Japar Sidik and Muta Harah (2003), (31) Sasekumar et al. (1989), (32) Arshad et al. (2001), (33) Arshad et al. (2008), (34) Choo and Liew (2005), (35) Muta Harah and Japar Sidik (2011), (36) Mohd Hanafi et al. (2008), (37) Mohd Hanafi et al. (2009), (38) Cob et al. (2009), (39) Roushon et al. (2010), (40) Adulyanukosol (2002), (41) Rattanachot and Prathep (2011), (42) Abu Hena et al. (2007), (43) Abu Hena and Ashraful (2009), (44) Chowdhury et al. (2011), (45) Wilson et al. (2005), (46) Kumaraguru et al. (2005), (47) Gangal et al. (2012)

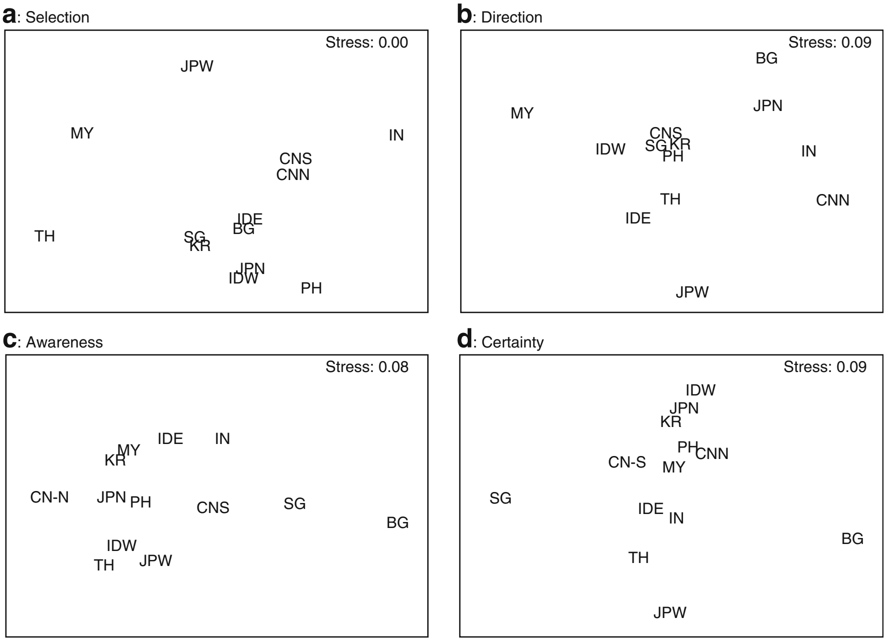

Fig. 20.2 Results of nonmetric multidimensional scaling (nMDS) showing dissimilarity in the characteristics of four ecosystem services (**a–d**) among the 13 seagrass beds in Asia. See Table 20.2 for the site codes

Table 20.5 Results of Mantel test on the correlation of the dissimilarity matrices on seagrass ecosystem services with distance, latitude, and seagrass species composition

	Independent variables		
Dependent variables	Distance	Differences in latitude	Dissimilarity in seagrass species composition
Selection of ecosystem services	$r = -0.092$ $p = 0.729$	$r = -0.203$ $p = 0.959$	$r = -0.214$ $p = 0.938$
Direction of changes	$r = 0.170$ $p = 0.089$	$r = 0.138$ $p = 0.102$	$r = 0.169$ $p = 0.098$
Public awareness	$r = 0.000$ $p = 0.464$	$r = -0.139$ $p = 0.878$	$r = 0.246$ $p = 0.072$
Data certainty	$r = -0.065$ $p = 0.655$	$r = -0.093$ $p = 0.754$	$r = 0.189$ $p = 0.086$

Direction of Changes and Their Driver

The direction of temporal changes in ecosystem services also varied greatly among sites and selected types (Table 20.4). Four sites indicated an improvement in food provisioning, indicating that the amounts harvested from these beds have increased, whereas the other nine sites indicated a degradation in food provisioning, showing decreasing levels of harvest from the seagrass beds.

For regulation services, overall decline was reported for almost all services and sites. The exceptions to this trend were two sites at Ikunoshima Estuary (western Japan) and Yuehu (northern China) where there was improvement in the regulating services from water purification and waste treatment at both sites and additionally in natural hazard regulation in the latter.

Among cultural services, educational value showed improvement at all the selected sites except for Southwest Johor (Malaysia). Recreation and ecotourism also showed improvement across all sites, with the exception of Barrang Lompo Island (eastern Indonesia), Banten Bay (western Indonesia), and Bakkhali Estuary (Bangladesh), where there was a decline.

Patterns in the direction of ecosystem service changes are similar for Koje Bay (Korea), Hepu (southern China), Bolinao (the Philippines), and Singapore. No obvious regional tendency was found among the 13 sites (Fig. 20.2b), with no significant differences detected between temperate and tropical seagrass beds (PERMANOVA: $F = 2.324$, $p = 0.176$). Again, the variation in dissimilarity was not significantly correlated with distance, latitude, or seagrass species composition (Table 20.5).

Public Awareness and Data Certainty

Public awareness of the selected ecosystem services varied among different types of services (Table 20.6). It was generally high for food provisioning in most sites except for Singapore, Bakkhali Estuary (Bangladesh), and Gulf of Manner (India). Awareness of local communities on regulation services was generally low, whereas that of cultural services varied greatly, with most sites indicating moderate awareness. Awareness of all the services was low in Bakkhali Estuary whereas it was high to medium in Yuehu (northern China) and Sg. Pulai Estuary (Malaysia).

Scores for data certainty followed the similar patterns to those for public awareness, with high to medium certainty for food provisioning (except for Singapore), and medium to low certainty for most regulating services (Table 20.7). The score was highly variable for cultural services. MDS plots for the awareness data and the certainty data showed similar patterns of variation with Bakkhali Estuary (Bangladesh) and Singapore separated from other sites. The similarity matrices of these two parameters were highly correlated with each other (Mantel test; $r = 0.637$, $p < 0.001$).

There was no latitudinal or regional tendency in the patterns found for awareness and data certainty as shown by nonsignificant variation between temperate and tropical regions (PERMANOVA; $F = 2.114$, $p = 0.154$ for the awareness score; $F = 1.173$, $p = 0.372$ for the certainty score) and by nonsignificant correlation with distance, latitude, and species composition (Table 20.5).

Table 20.6 Summary of the public awareness of ecosystem services in seagrass beds

Types of ecosystem services	JPN	JPW	KR	CNN	CNS	PH	IDE	IDW	SG	MY	TH	BG	IN
Provisioning services													
Food	High	High	High	High	Medium	High	Medium	High	Low	High	High	Low	Low
Genetic resources	–	–	–	–	Medium	–	–	–	–	Medium	–	–	Medium
Biochemicals and medicines	–	Medium	–	–	–	–	–	–	–	High	–	–	–
Regulating services													
Climate regulation	Low	–	–	–	–	Medium	–	Low	–	–	–	–	Low
Erosion regulation	Low	–	Low	–	–	Low	High	Low	Low	Medium	Low	Low	–
Water purification and waste treatment	Medium	Low	High	High	Low	–	Medium	Low	Low	Medium	Low	Low	Medium
Natural hazard regulation	–	–	–	Medium	Low	Low	Low	–	–	–	–	Low	Medium
Cultural services													
Cultural diversity	–	Medium	–	–	–	–	–	–	–	–	–	–	–
Spiritual and religious values	–	–	–	–	–	–	–	–	–	–	High	–	–
Educational values	Medium	High	Medium	High	Medium	Medium	High	High	Medium	Medium	High	Low	–
Inspiration	–	–	–	–	–	–	–	–	–	–	High	–	–
Aesthetic values	–	–	Medium	High	–	–	–	–	Medium	–	–	–	–
Recreation and ecotourism	Low	High	Medium	High	Medium	Medium	Low	Medium	Medium	–	–	Low	Medium

Table 20.7 Summary on data certainty of ecosystem services in seagrass beds

Types of ecosystem services	JPN	JPW	KR	CNN	CNS	PH	IDE	IDW	SG	MY	TH	BG	IN
Provisioning services													
Food	High	High	High	High	High	High	Medium	High	Low	High	Medium	Medium	High
Genetic resources	–	–	–	–	Medium	–	–	–	–	Medium	–	–	Low
Biochemicals and medicines	–	Low	–	–	–	–	–	–	–	High	–	–	–
Regulating services													
Climate regulation	Low	–	–	–	–	Medium	–	Low	–	–	–	–	Medium
Erosion regulation	Low	–	Low	–	–	Medium	Medium	Low	Medium	Medium	Medium	Low	–
Water purification and waste treatment	Medium	High	Medium	High	Medium	–	Medium	Low	Low	Medium	Medium	Low	Medium
Natural hazard regulation	–	–	–	Medium	Low	Medium	Low	–	–	–	–	Low	Medium
Cultural services													
Cultural diversity	–	Medium	–	–	–	–	–	–	–	–	–	–	–
Spiritual and religious values	–	–	–	–	–	–	–	–	–	–	Medium	–	–
Educational values	Medium	High	Medium	Medium	Medium	Medium	High	High	Medium	Medium	High	Low	–
Inspiration	–	–	–	–	–	–	–	–	–	–	High	–	–
Aesthetic values	–	–	Medium	Medium	–	–	–	–	Medium	–	–	–	–
Recreation and ecotourism	Medium	High	Medium	Medium	High	Medium	Low	Low	High	–	–	Low	Medium

Discussion

Coastal ecosystems offer various types of ecosystem services that are important both economically and culturally (Constanza et al. 1997; Hein et al. 2006). However, long-term quantitative data are mostly lacking in Asian countries, despite the high proportion of marine diversity that is found in this region. The present study is a first attempt to analyze the status of ecosystem services provided by seagrass beds in Asia, encompassing both temperate and tropical regions. It gives an overview of the status of seagrass beds in Asia based on expert assessment where quantitative information is lacking and provides a baseline and directions for future studies.

The seagrass beds chosen in this study varied greatly in latitude, meadow size, and species composition. Furthermore, there were no significant geographic trends in the selection of important ecosystem services and in the pattern of temporal changes. Food provisioning was the overriding ecosystem function across all sites that was identified by local experts, followed by services such as water purification and waste treatment, erosion regulation, educational value, and recreation and ecotourism, identified based on the general list by Millennium Ecosystem Assessment (2003). This result indicates that the recognition of important ecosystem services of seagrass beds is shared internationally among experts who are scientists and ecosystem managers.

The direction of changes in these ecosystem services showed some common trends across different sites, with provisioning and regulating services showing a downward or degrading trend whereas cultural services of seagrass beds showed the opposite trend. For food provisioning, the declines in most sites were related to both overfishing and degradation of the seagrass bed by pollution and land development, which is a theme that is identified repeatedly in coastal habitats throughout Asia (Fortes 1988; Duarte 2002; Silvestre et al. 2003; Unsworth and Cullen 2010). Even at sites where food provisioning is reported to be improving, it is important to understand the context in which this change is occurring. For example, an increase in food provisioning services in terms of net harvest is not necessarily positive as the improvement may be driven by an increased demand for seafood, hence a corresponding increase in production through increased or intensified fisheries and aquaculture activity. There is no indication of whether the increased production is sustainable, and hence these sites could see deterioration in the future should production continue above ecologically sustainable levels.

The decreasing trend observed in regulating services at many sites reflects the fact that human-induced impact is a serious problem for seagrass beds throughout Asia, and this hold true when we explore the factors affecting specific sites in this study. For example, high rates of sedimentation and eutrophication of coastal waters caused by environmentally unfriendly practices in aquaculture have been observed in Akkeshi Estuary in northern Japan (Hokkaido Environmental Science Center 2005), Koje Bay in southern Korea (Yoon et al. 2009), and Bolinao in the Philippines (Holmer et al. 2002; San Diego-McGlone et al. 2008), which may lead to seagrass loss from decreased light availability. Another very serious threat is the

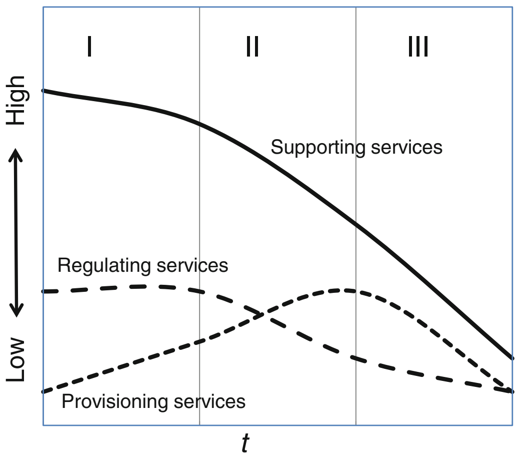

Fig. 20.3 A schematic model describing temporal changes in the relationship between provisioning and regulating services with the degradation of supporting services. See text for the explanation of the three phases (*I*, *II*, *III*)

direct loss of seagrass beds from land development and reclamation, which occurred in Banten Bay, western Indonesia (Douven et al. 2003), and Sg. Pulai Estuary, Malaysia (Japar Sidik and Muta Harah 2003; Muta Harah and Japar Sidik 2011). The exceptions are found in Seto Inland (western Japan) and in Yuehu (northern China), where regulating services have been improving over the past two decades from better water quality and some successful restoration projects, resulting in an increase in seagrass area (Jia et al. 2003; Yamamoto 2003).

Studies on terrestrial and freshwater ecosystems have shown that trade-offs often arise when it comes to management decisions on the utilization of ecosystem services and conservation (Rodríguez et al. 2006). In most cases, unsustainable use of ecosystems for purposes of maximizing direct services (e.g., provisioning services such as food production) inevitably results in the degradation of not only said service, but also in indirect services such as regulating (e.g., nutrient cycling) and cultural (e.g., educational values) services (Bennett et al. 2009; Carpenter et al. 2009). In our analyses, negative relationships between food provisioning and regulation services were found only in a few sites. In the case of Akkeshi-ko Estuary (northern Japan), it is likely that intensive use of the estuary for aquaculture caused a decrease in water quality (Nakaoka and Matsuda 2011). However, for other sites such as Ikunoshima Estuary (western Japan) and Bakkhali Estuary (Bangladesh), the relationship was less clear as the cause may have been one direct impact or several compounding factors, although no studies have investigated their links. In the other sites, both provisioning and regulating services were experiencing decline and thus positively correlated except for Yuehu (northern China), where both services were improving after the recovery of the eelgrass bed (Jia et al. 2003).

The variable relationship between provisioning, regulating, and supporting services observed at many sites may be viewed as phases, which describe changes in the balance of each service along a spectrum (Fig. 20.3). Phase I shows high levels of regulating services such as primary productivity and nutrient cycling, over that of provisioning services, which in turn can increase while maintaining regulating services in good condition (Fig. 20.3). Phase II shows intensive exploitation of provisioning services over sustainable levels that would lead to a decrease in both supporting and regulating services, leading to trade-offs between the two. Continued and sustained exploitation of provisioning services over the threshold level of regulating services leads to a decrease in all three ecosystem services (Phase III).

It is likely that the current situation in each study site reflects the different phases of these gradients: Yuehu (northern China) in Phase I, Akkeshi-ko Estuary (northern Hokkaido) in Phase II, and most other sites in Phase III. In terrestrial and freshwater ecosystems, the shift in the status of ecosystem services can occur nonlinearly with a threshold (Kinzig et al. 2005). It is unknown how these temporal changes occur in seagrass beds during the process of ecosystem degradation and what the associated thresholds for the ecosystem services in the seagrass beds might be.

Changes in cultural services were generally positive at most sites, especially for the educational value of seagrass beds. In each Asian country, there is increased recognition within the population of the value of natural ecosystems, as shown by the middle to high scores of public awareness. The improvement is partly from translation of research results into outreach and advocacy at both educational and institutional levels (Fortes et al. 2007), and through community-based monitoring programs such as Seagrass Watch (McKenzie et al. 2000). Improvement in the recreation and ecotourism industries in most regions may also be related to increased awareness of the value of coastal ecosystems, although it should be noted that excess and unregulated recreational use can also degrade habitat quality (Milazzo et al. 2002; Davenport and Davenport 2006). In fact, the recreational use of seagrass beds is in decline for sites where there was habitat loss and deterioration, such as in Banten Bay (western Indonesia) and Bakkhali Estuary (Bangladesh).

As expected, public awareness of seagrass ecosystem services was high for food provisioning in most countries, which is tightly related to the economic status of local communities. In contrast, the awareness of regulating services was low, as these services are intangible and thus difficult to comprehend without specific scientific outreach from specialists. It has been pointed out that there is a large gap between scientific knowledge and public awareness on the role of seagrass ecosystems compared to other types of coastal habitats such as coral reefs and mangroves (Orth et al. 2006; Duarte et al. 2008). The variation in data certainty is likely to be related to the needs of local communities and the direction of scientific endeavor, which translates to their level of awareness. For example, the amount of reliable data for food provisioning services was relatively high as these services are directly related to human needs and activity; this translates to more scientific resources channeled toward this service, which then contributes to both awareness of the public (through outreach) and the certainty of data from local experts.

One of the unexpected findings is that the level of awareness and data certainty did not differ significantly between temperate seagrass beds in economically developed countries (such as Japan and Korea), and tropical areas in South and

Southeast Asia, which have a higher proportion of developing countries. It should be noted, however, that the results of the present analyses were based on data from one or two seagrass beds from each country, and that the obtained regional variation may not be necessarily indicative of variation in economic situation or decision-making processes among countries. Nevertheless, the lack of scientific data on functions and services of ecosystems, especially on those of regulating services, and insufficient outreach to local communities and stakeholders remains a major concern in all Asian countries. Promotion of more systematic and effective scientific monitoring and research on biodiversity and the ecosystem functioning of coastal areas are both highly needed to address the paucity of data and to reverse the direction of changes in ecosystem services, which are still being degraded in most Asian regions.

In conclusion, the comparative analyses on ecosystem services based on expert knowledge clarified some general and specific aspects of the status of seagrass beds in Asian regions for which quantitative scientific data are lacking. The approach is a positive step in the attempt to deepen our understanding of coastal ecosystems, and the results obtained will be used as baseline data for planning effective conservation and management strategies under multiple human impacts. The current dataset can be further improved by covering more sites in Asia and by replicating the analysis in other regions of the world and on other coastal habitats such as mangroves and coral reefs. This approach allows for within-group, cross-regional, and cross-habitat comparisons, which may delineate interesting trends that are not yet apparent.

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