Title

Fine-scale distribution of tropical seagrass beds in Southeast Asia

Names of authors

Kenji Sudo[1,2]*, Masahiro Nakaoka[2]

Affiliations and addresses of the authors

1 Graduate School of Environmental Science, Hokkaido University, Aikappu 1, Akkeshi, Hokkaido 088-1113, Japan

2 Akkeshi Marine Station, Field Science Center for Northern Biosphere, Hokkaido University, Aikappu 1, Akkeshi, Hokkaido 088-1113, Japan

Corresponding author

Kenji Sudo

Graduate School of Environmental Science, Hokkaido University.

Akkeshi Marine Station, Aikappu, Akkeshi-town, Hokkaido 088-1113, Japan

Tel.: +81(153)-52-2056

E-mail: ksudo.hokudai@gmail.com

Abstract

Southeast Asia is a hotspot of global seagrass diversity, offering valuable ecosystem services for human life. However, historically there have been large gaps in the scientific knowledge of the distribution of seagrass beds in this region. Information on the distribution has not been updated in global databases since the publication of the World Seagrass Atlas in 2003, which was based on data mostly obtained up until the late 1990s. We collected more recent data on seagrass bed distribution from 9 ASEAN countries plus southern China and southern Japan, and integrated these data into a GIS-database. A total of 1064 polygon data and 937 points data were uploaded in this paper, which were obtained from 107 scientific articles and reports published after 2000, including those written in local languages. Among them, 7.3 % of the data have associated information on seagrass bed size and 35.3 % have associated information on seagrass species composition. Data obtained from Vietnam, Cambodia, Singapore, Timor-Leste and Southern China cover almost all the coastlines of each country, whereas data for the Philippines, Indonesia, Malaysia Myanmar, Thailand still have large gaps in areal coverage. The data set has a few points from Brunei Darussalam, the Paracel Islands, Spratly Islands and Pratas Islands, which are areas that we lacked information on for a long time. The obtained data will be useful to understand the current status of seagrass beds and to help facilitate better conservation and management of coastal areas in this region.

Key words

ASEAN countries

Geographic information system (GIS)

Coastal ecosystem

Seagrass bed area

Literature survey

1. INTRODUCTION

Seagrass beds are one of the most important coastal habitats globally, offering valuable ecosystem services for human life (Constanza et al. 1997; McArthur and Boland 2006; Unsworth and Cullen 2010; Nakaoka et al. 2014). This habitat has been threatened by various types of human-induced stressors, including overexploitation, eutrophication, coastal development, sedimentation and damages by fisheries and boat activities, and global climate changes (Orth et al. 2006, Waycott et al. 2009, Wilkinson and Salvat 2012).

Southeast Asia is a hotspot of global seagrass diversity with 24 species out of <60 world species present in this region (Short et al. 2007). Seagrass beds in this region is characterized by mixed, multispecific meadow with more than 10 species are sometimes co-occur in a single stand (Soe-Htun et al. 2018, Vermaat et al. 1995). Basic information on their biology and ecology has been accumulated by past studies, such as their biomass and productivity (Vermaat et al. 1995, Duarte et al. 1998) genetic diversity (Nakajima et al. 2014), species interaction and their responses to disturbances such as siltation and tsunamis (Terrados et al. 1998, Whanpetch et al. 2010). However, a large knowledge gap still remains on the distribution, species diversity and abundances of tropical seagrass species in this region (Fortes et al. 2018). Especially, information on the declining seagrass beds is limited due to a lack of reliable data on seagrass bed distribution and its long-term changes (Yaakub et al. 2014, Yaakub et al. 2018, Unsworth et al. 2018). In a global analysis on temporal changes in seagrass beds,

Waycott et al. (2009) estimated that seagrass beds were disappearing at a rate of 7 % year $^{-1}$ globally. However, they could include only two data from the East Asia (Japan and South Korea), and no data from Southeast Asian countries. Considering the rapid economic development of coastal areas of Asia, the estimated decreasing rate of global seagrass beds was likely underestimated without the information from this region. There is an urgent need for sharing information on the current status of seagrass bed distribution in this region to facilitate the management of marine biodiversity and sustainable use of marine resources.

Open-access data promote advancement of science, research efficiency and science-based problem solution through the utilization by various type of users; not only scientists but also practitioners and policy makers. Open-access data on seagrass bed distribution globally have been available since 2003 following the publication of the World Atlas of Seagrasses (WAS) and by the online release of its GIS data set through Ocean Data Viewer also in 2003 (Green and Short 2003; UNEP-WCMC and Short 2016; http://data.unep-wcmc.org/ 9th, April 2018 accessed). However, the accuracy of these GIS data was sometimes very low in the Asian region. In Vietnam, for example, some seagrass beds were unrealistically located more than 20 km far from coastal line, which was likely caused by errors in GPS coordinates. In Singapore, a seagrass bed was located in the middle of land which was probably a record of herbarium in a botanical garden. In addition, data from Southeast Asia have not updated since 2003 in this dataset. Nevertheless, with the increasing awareness of the importance of seagrass beds,

multiple surveys on the status of seagrass beds have been conducted by governmental managers and scientists in Asian countries since the 2000s, although most of them have been published in local literature in native languages (Fortes et al. 2018), which are difficult to access by internet surveys in English.

This data paper provides recent data on tropical seagrass bed distribution in Southeast Asia. We compiled data on seagrass distribution from the literature and reports locally published in each country after 2000 and created a geographic information system (GIS) database. The obtained data were presented either by polygon data (a total of 1064 data) or point data (937 data) both associated with the information on seagrass bed area and seagrass species composition if available. The obtained fine-resolution, broad-scale data will be useful to understand the current status of seagrass beds and to help facilitate better conservation and management of coastal areas in this region that are still under great threat from various types of human-induced stressors. We expect the open-access data provided by this data paper will be used by various types of users. For example, scientists with new ideas on marine ecology can use these data for research such as exploration on seagrasses and associates in deeper parts, broad-scale GIS-based estimation of seagrass distribution and its future forecast, and a broad-scale analysis of seagrass-associated faunal organisms. Policy makers and practitioners can utilize the data for setting conservation plans such as designing marine protected areas and setting regulation for coastal resource uses.

The complete data set for this abstract published in the Data Paper section of the journal is available in electronic format in Ecological Research Data Paper Archives at http://db.cger.nies.go.jp/JaLTER/ER_DataPapers/archives/2020/ ERDP-2020-13.

2 DATA DESCRIPTION

2.1 Identifier

ERDP-2020-13

2.2 Contributor

2.2.1 Dataset owner

Kenji Sudo

Graduate School of Environmental Science, Hokkaido University.

Akkeshi Marine Station, Aikappu, Akkeshi-town, Hokkaido 088-1113, Japan

Tel.: +81(153)-52-2056

E-mail: ksudo.hokudai@gmail.com

2.2.2 Contact person

Kenji Sudo

Graduate School of Environmental Science, Hokkaido University.

Akkeshi Marine Station, Aikappu, Akkeshi-town, Hokkaido 088-1113, Japan

Tel.: +81(153)-52-2056

E-mail: ksudo.hokudai@gmail.com

2.3 Geographic coverage

The geographic scope of this study covers from S 11.010º to N 30.424º in latitude and from E 94.229 º to 140.702 º in longitude (geodetic system: WGS84). The area includes all the

coastlines of Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste, Vietnam, and the southern coasts of China and Japan. The northern boundary is set so that it covers the northern limit of tropical seagrass species; i.e., Fujian province in China (Zheng et al 2013) and the southern part of Kagoshima prefecture in Japan (Nature Conservation Bureau, Environment Agency and Marine Parks Center of Japan, 1994).

2.4 Methods

2.4.1 Literature collection

Data were collected from more than 107 scientific articles or reports. We searched the literature using the terms “seagrass” and “target country name” through the Web of Science, Google Scholar and Google. In an online survey, we looked for references not only in English, but also in local Asian languages (Japanese, Chinese, Vietnamese, and Indonesian). Together with the online literature survey, we also visited Vietnam and asked key researchers there about the seagrass distribution literature published in Vietnamese. From the collected literature, we only use seagrass distribution literature and reports published after 2000.

2.4.2 Data processing

We compiled data into two formats to make the GIS database; point data and polygon data.

Seagrass bed distribution maps in the original literature were georeferenced using the ArcGIS georeference tool, and seagrass bed outlines were manually traced using the editor tool. In some of the literature, the position of seagrass beds are shown over large areas that sometimes extend to areas of very deep water (> 100 m). For these data, we narrowed down the distribution to the shallower, coastal area to which tropical seagrass can survive (Duarte 1991). As a result, a total of 1064 polygon data and 937 points data were installed in the GIS database (Fig.1, Table1). Each point and polygon datum has associated data on the seagrass species composition, and each point datum also has that of seagrass bed area (ha), if available.

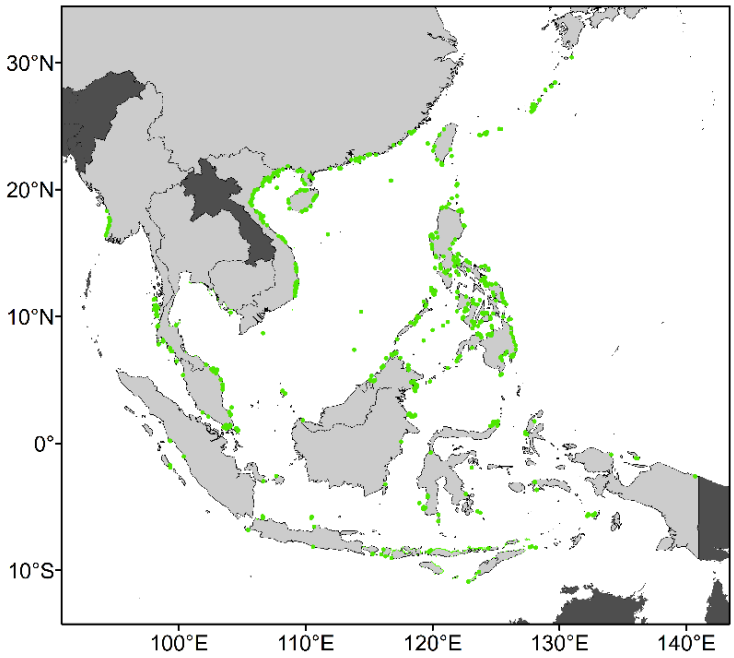

Fig.1. Plotted seagrass beds in Southeast Asia from the current database for the period of 2000-2019.

Table1 The number of point and polygon data in each country

Country	Number of point data	Number of polygon data	Total
Brunei Darussalam	2	0	2
Cambodia	0	17	17
Indonesia	182	343	525
Malaysia	91	0	91
Myanmar	58	0	58
the Philippines	312	102	414
Singapore	43	9	52
Southern China	95	0	95
Southern Japan	45	157	202
Thailand	20	346	366
Timor-Leste	0	30	30
Vietnam	89	60	149
Total	937	1064	2001

2.5 Data structure

2.5.1 Data files

Data consists of four data files shown in Table 2.

Table 2 Outline of each data file

Variables in file name	Description
Seagrass point DB.csv	Attribute table of point data for seagrass bed distribution including coordinates, area and seagrass species composition
Seagrass polygon DB.csv	Attribute table of polygon data for seagrass bed distribution including coordinates, area and seagrass species composition
Reference DB.csv	Reference database of both point and polygon data
Seagrass polygon DB.shp	Polygon data of seagrass bed distribution from the literature for GIS compressed into the commonly used zip format

2.5.2 File format

The data files are saved in the comma delimited (csv) text file format in UTF-8 encoding. The GIS polygon data files are formatted in shape file and compressed into the commonly used zip format.

2.5.3 Variable definitions

Table 3 shows variable definitions for Seagrass point DB.csv.

Table 4 shows variable definitions for Seagrass polygon DB.csv.

Table 5 shows variable definitions for Reference DB.csv.

Table 6 shows variable definition for Seagrass polygon DB.shp.

Table 3 List of variables and their definitions for Seagrass point DB.csv

Variables in file name	Description
ID	ISO country code alpha-3, data category and serial number
Locality	Local place name
Site	Site name from the literature
Lat	Latitude coordinated WGS84 DDD
Long	Longitude coordinated WGS84 DDD
Reference	First author name, publication year of the information

Source	Detailed data information source from the reference
Area Literature	Area (ha) information from the literature
Remarks	Remarks
Species	Presence or absence of each seagrass species from the literature at the site; 1: presence, 0: absence, NA: no information Acronyms denote genus and species; Cs: *Cymodocea serrulata,* Cr: *Cymodocea rotundata,* Ea: *Enhalus acoroides,* Hb: *Halophila beccarii,* Hd: *Halophila decipiens,* Hm: *Halophila minor*, Ho: *Halophila ovalis,* Hs: *Halophila spinulosa,* Hp: *Halodule pinifolia,* Hu: *Halodule uninervis,* Rm: *Ruppia maritima,* Si: *Syringodium isoetifolium,* Th: *Thalassia hemprichii,* Tc: *Thalassodendron ciliatum,* Zj: *Zostera japonica*

Table 4 List of variables and their definitions for Seagrass polygon DB.csv

Variables in file name	**Description**
ID	ISO country code alpha-3, data category and serial number
Locality	Local place name
Site	Site name from the literature
Lat	Latitude coordinated WGS84 DDD Weighted center of the polygon
Long	Longitude coordinated WGS84 DDD Weighted center of the polygon
Reference	First author name, publication year of the information
Source	Detailed data information source from the reference
Area GIS	Calculated area (ha) from traced ~~of~~ polygon data using GIS
Area Literature	Area (ha) information from the literature
Remarks	Remarks
Species	Presence or absence of each seagrass species from the literature at the site; 1: presence, 0: absence, NA: no information Acronyms denote genus and species;

	Cs: *Cymodocea serrulata,* Cr: *Cymodocea rotundata,* Ea: *Enhalus acoroides,* Hb: *Halophila beccarii,* Hd: *Halophila decipiens,* Hm: *Halophila minor*, Ho: *Halophila ovalis,* Hs: *Halophila spinulosa,* Hp: *Halodule pinifolia,* Hu: *Halodule uninervis,* Rm: *Ruppia maritima,* Si: *Syringodium isoetifolium,* Th: *Thalassia hemprichii,* Tc: *Thalassodendron ciliatum,* Zj: *Zostera japonica*

Table 5 List of variables and their definitions for Reference.csv

Variables in file name	**Description**
ID	ISO country code alpha-3 and serial number
Reference	Citation and Digital Object Identifier (DOI)

Table 6 List of variable and definition for Seagrass polygon DB.shp

Variable in file name	**Description**
ID	ISO country code alpha-3 and serial number

2.6 Accessibility

2.6.1 License

2.6.2 Location of storage

http://db.cger.nies.go.jp/JaLTER/ER_DataPapers/archives/2020/ERDP-2020-13

ACKNOWLEDGMENTS

We are grateful to Dr. Nguyen Van Quan, Dr. Dam Duc Tien, MSc Dau Van Thao and Dr. Cao Van Luong (Vietnam Academy of Science and Technology) for their cooperation in obtaining the Vietnamese literature data. We appreciate two reviewers for their comments which help to improve the manuscript and data. We thank Ms.Rebecca Brydon-Maxwell from Edanz Group (www.edanzediting.com/ac) for editing a draft of this metadata. This study was supported by the Environment Research and Technology Development Fund (S-15: Predicting and Assessing Natural Capital and Ecosystem Services) of the Ministry of the Environment, Japan, the Belmont Forum “TSUNAGARI” fund by JST (Japan Science and Technology Agency), SATREPS BlueCARES by JST-JICA (Japan International Cooperation Agency), and “Research and Education Network on Coastal Ecosystems in Southeast Asia” by JSPS

(Japan Science Promotion Society) Core-to-Core Program.

REFERENCES

Costanza R, D'Arge R, Groot R De, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, Belt M Van Den (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260. https://doi.org/10.1038/387253a0

Duarte CM (1991) Seagrass depth limits. Aquatic botany, 40(4), 363-377. https://doi.org/10.1016/0304-3770(91)90081-F

Fortes MD, Ooi JLS, Tan YM, Prathep A, Bujang JS, Yaakub SM (2018) Seagrass in Southeast Asia: a review of status and knowledge gaps, and a road map for conservation. Botanica Marina, 61(3), 269-288. https://doi.org/10.1515/bot-2018-0008

Green EP, Short F (2003) World atlas of seagrasses, Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, USA. https://doi.org/10.1515/BOT.2004.029

McArthur LC, Boland JW (2006) The economic contribution of seagrass to secondary production in South Australia. Ecological Modelling 196, 163–172. https://doi.org/10.1016/j.ecolmodel.2006.02.030

Nakaoka M, Lee KS, Huang X, Almonte T, Bujang J, Kiswara W, Ambo-Rappe R, Yaakub S,

Prabhakaran MP, Abu Hena, MK, Hori M, Zhang P, Prathep A, Fortes M (2014) Regional Comparison of the Ecosystem Services from Seagrass Beds in Asia. in: Integrative observations and assessments. pp. 367–391. Springer, Tokyo. https://doi.org/10.1007/978-4-431-54783-9_20

Nakajima Y, Matsuki Y, Lian C, Fortes MD, Uy WH, Campos WL, Nakaoka M, Nadaoka K, (2014) The Kuroshio Current influences genetic diversity and population genetic structure of a tropical seagrass, Enhalus acoroides. Molecular Ecology, 23(24), 6029-6044. https://doi.org/10.1111/mec.12996

Nature Conservation Bureau, Environment Agency and Marine Parks Center of Japan (1994) The Report of the Marine Biotic Environment Survey in the 4th National Survey on the Natural Environment. Vol.2 Algal and Sea-Grass Beds.

Orth RJ, Carruthers TJB, Dennison WC, Duarte CM, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Olyarnik S, Short FT, Waycott M, Williams SL (2006) A Global Crisis for Seagrass Ecosystems. Bioscience, 56(12), 987-996. https://doi.org/10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2

Short F, Carruthers T, Dennison W, Waycott M (2007) Global seagrass distribution and diversity: a bioregional model. Journal of Experimental Marine Biology and Ecology 350(1), 3-20. https://doi.org/10.1016/j.jembe.2007.06.012

Soe-Htun U, Maung A, Mon S, Tun TZ, Hteik A, Lwin ML, Tun Z, Lunn UZ, Murray-Jones S (2018) Seagrass surveys in the southern Rakhine coastal region, Myanmar: biodiversity, distribution and coverage. Journal of Aquaculture & Marine Biology 7(2):103–110. https://doi.org/10.15406/jamb.2018.07.00193

Terrados J, Duarte CM, Fortes MD, Borum J, Agawin NS, Bach S, Thampanya U, Kamp-Nielsen L, Kenworthy WJ, Geertz-Hansen O & Vermaat J (1998) Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. Estuarine, Coastal and Shelf Science, 46(5), 757-768. https://doi.org/10.1006/ecss.1997.0304

UNEP-WCMC, Short FT (2016) Global distribution of seagrasses (version 4.0).Fourth update to the data layer used in Green and Short (2003) Cambridge (UK): UNEP World Conservation Monitoring Centre. URL: http://data.unepwcmc.org/datasets/7

Unsworth RK, Cullen LC (2010) Recognising the necessity for Indo‐Pacific seagrass conservation. Conservation Letters 3(2), 63-73. https://doi.org/10.1111/j.1755-263X.2010.00101.x

Unsworth RK, Ambo-Rappe R, Jones BL, La Nafie YA, Irawan A, Hernawan UE, Moore AM & Cullen-Unsworth LC (2018) Indonesia's globally significant seagrass meadows are under widespread threat. Science of the Total Environment, 634, 279-286. https://doi.org/10.1016/j.scitotenv.2018.03.315

Vermaat JE, Agawin NS, Duarte CM, Fortes MD, Marba N & Uri JS (1995) Meadow maintenance, growth and productivity of a mixed Philippine seagrass bed. Marine Ecology Progress Series, 124, 215-225. https://doi.org/10.3354/meps124215

Whanpetch N, Nakaoka M, Mukai H, Suzuki T, Nojima S, Kawai T & Aryuthaka C (2010) Temporal changes in benthic communities of seagrass beds impacted by a tsunami in the Andaman Sea, Thailand. Estuarine, Coastal and Shelf Science, 87(2), 246-252. https://doi.org/10.1016/j.ecss.2010.01.001

Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR, Kendrick GA, Kenworthy WJ, Short FT, Williams SL (2009) Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences 106, 12377–12381. https://doi.org/10.1073/pnas.0905620106

Wilkinson C & Salvat B (2012) Coastal resource degradation in the tropics: does the tragedy of the commons apply for coral reefs, mangrove forests and seagrass beds. Marine Pollution Bulletin, 64(6), 1096-1105. https://doi.org/10.1016/j.marpolbul.2012.01.041

Yaakub SM, Ooi JLS, Buapet P, & Unsworth RK (2018) Seagrass research in Southeast Asia. Botanica Marina, 61(3), 177-179. https://doi.org/10.1515/bot-2018-0046

Zheng F, Qiu G, Fan H, Zhang W (2013) Diversity, distribution and conservation of Chinese

seagrass species. Biodiversity Science 21(5): 517-526.

https://doi.org/10.3724/SP.J.1003.2013.10038