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Seagrass meadows for fisheries in Indonesia: a preliminary study

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Seagrass meadows for fisheries in Indonesia: a preliminary study

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Abstract. Seagrass meadows are among the most productive ecosystems on earth and are of great importance to support an abundance and diverse fish assemblages that form the basis for artisanal fisheries, especially in the tropics. Fisheries are vital in maintaining food security, and therefore the ecosystems that support these fisheries are also essential. Seagrass ecosystems contribute to fishery productivity, and seagrass fisheries are especially common in the Indo-Pacific region, where seagrass beds and their associated fauna are heavily exploited. However, these fisheries remain largely undocumented. Within the Indo-Pacific region, Indonesia contributes significantly to seagrass biodiversity and global seagrass extent. Seagrass fisheries undoubtedly exist in Indonesia, but publications on this topic are rare. Therefore, there is a need to highlight the extent, importance, and status of fisheries exploitation in the seagrass meadows of Indonesia. The aims of this study were to determine the importance of seagrass meadows in supporting fisheries productivity and examining the variability of seagrass fisheries in Indonesia. A literature search of published data on fisheries activities in seagrass meadows in Indonesia was conducted from March-May 2020. Google Scholar database was searched using the most specific keywords in English and Indonesian, for example, "seagrass" AND "fisheries" AND "Indonesia", "seagrass fisheries" AND "Indonesia", "Perikanan Skala Kecil" DAN "Padang Lamun", in the title, abstract or keywords, in order to obtain information from the few papers on seagrass fisheries in Indonesia published in English (international journals) and Indonesian. Additional data on seagrass fisheries and the fishing methods/gears used were collected by interviewing people who live or work in areas with few or no published data to gain a broader picture of seagrass fisheries in Indonesia. It was found that seagrass fisheries occur in almost all nearshore seagrass areas in Indonesia, including around many small islands. Many fishing gears are used in these fisheries, the most common being gill nets, traps, and gleaning (directly picking up fauna from the seagrass beds using bare hands or very simple tools). Therefore, from a socioeconomic perspective, seagrass beds are extremely important for the livelihoods of coastal and island communities in Indonesia.

22 Introduction

Seagrasses are true flowering plants that have evolved to live in the marine environment; they include approximately 72 different species belonging to four major groups [31]. Although seagrass meadows often receive little attention compared to other marine ecosystems [2], seagrass is one of the dominant primary producers especially in coastal waters around the world, providing an important foundation for marine biological communities and playing important roles for coastal communities, for example through their contributions to fishery yields and cultural values [3]. Seagrass ecosystems are also crucial ecosystem service providers throughout their global extent (up to a maximum of 600,000 km²),

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are found along the shores of all continents (except Antarctica) to a maximum depth of 50 m [4,5]. Seagrass meadows in Southeast Asia have the highest seagrass diversity in the world, with a recently estimated extent of 36,762.6 km² [6].

In the last few decades, seagrasses have received greater attention with the recognition of their important ecosystem services. Seagrasses were ranked as one of the most ecologically and economically valuable biological systems on earth [7]. They also provide services that are less or more obvious such as nutrient and carbon cycling, acting as a carbon sink, and carbon exporter to sediments outside seagrass meadows and in the deep sea [8,9]. Moreover, seagrass ecosystems rank with mangroves and coral reefs in terms of primary production [10], and seagrass production was estimated to be responsible for up to 15% of the ocean's annual net carbon production [11].

Another important aspect is the physical structure for recruitment and attachment of a variety of small organisms increasing with seagrass presence, leading to a higher abundance and diversity of marine organisms in seagrass bed compared with bare areas [12]. Different morphological structures of seagrass leaves and stems enhance the attachment of numerous and abundance of epiphytes which are the food preference of epifaunal organisms [13]. Furthermore, many seagrass fishes also depend on the epiphytes and/or the epifaunal organisms associated in seagrass beds for food [5,14]. Thus, seagrasses play a significant part in the food web of marine areas and are commonly perceived as nursery grounds as they act as a source of food and shelter for a variety of marine organisms [15,16]. This leads to the important ecosystem services of the seagrass ecosystem, i.e., provisioning and supporting services, where seagrass facilitates and provides food through fisheries [17–19].

Seagrass meadows provide important support to fisheries in many ways, for example, through providing ecological role in the life cycle-, nursery habitat for a critical stage of juvenile period-, foraging habitat-, of some important fisheries commodities [18]. Some of the good examples on how seagrass ecosystem economically benefit fisheries comes from shrimp fisheries in Queensland, Australia which was estimated as AUS 1.2 million y⁻¹ [20]; seagrass supported fisheries have been valued at US\$ 100 million y⁻¹ in the Gulf waters of South Australia [21]; a major loss of seagrass in South Australia resulted in a 40% reduction in catch of a coastal marine fish, the King George whiting [18]; seagrasses contribute as much as \$A 230,000 ha⁻¹ y⁻¹ (153,000 € ha⁻¹ y⁻¹) to onshore fisheries in Gran Canaria (eastern Atlantic) [22].

The provisioning services supporting fish are unlikely to be the same for all seagrass meadows, as the structure they create can be different depending on numerous environmental and biological factors. The higher structural complexity of seagrass bed was related to higher species richness, abundance, and biomass of fish in Ambon Bay, Indonesia [23]. Moreover, this study found that smaller fish preferred dense seagrass of smaller-sized seagrass species and moved to a less dense bed of large-sized seagrass with increasing size. Studies in East Africa found that the presence of areas with seagrass meadows positively influenced adult densities of many reef fish species on adjacent coral reefs [24].

The role of seagrasses in provisioning high abundance and diversity of fishes is an important foundation for seagrass fisheries to be present in all seagrass regions or adjacent areas [17]. Indonesia has some of the most extensive and diverse seagrass meadows in the world, and it could be assumed that seagrass fisheries would be widespread in this region. However, information on the nature and existence of such fisheries in Indonesia lacks in the literature, so that they are poorly understood. This preliminary literature review synthesizes what is known about the nature of seagrass fisheries and their presence in Indonesia.

2. Methodology

The literature search was conducted from March-May 2020. We compiled studies on seagrass fisheries in Indonesia from all types of published literature available in the Google Scholar database. The search included those studies which contained terms "seagrass" AND "fisheries" AND "Indonesia" in the title, abstract, or keywords. This search resulted in a total of 10,800 results. The abstracts of the documents were screened to ascertain the relevance of the studies, and we found that many documents were not really relevant to this study.

The second search was done with more specific terms, “seagrass fisheries” AND “Indonesia”. We found 95 results from this second search, and after screening the abstracts, the results were narrowed down to 25 papers relevant to this study; 10 papers specifically presented seagrass fisheries in Indonesia. However, they have all focused on seagrass related fisheries in Sulawesi, one out of 7 large islands in Indonesia. We then performed a third search using the Indonesian terms “Perikanan Skala Kecil” DAN “Padang Lamun” in order to find related papers published in Indonesian literature with a wider geographical coverage within Indonesia. We had 62 results from this search, of which 12 papers were relevant.

A fourth search was performed with the same Indonesian keywords, but using Google Search, in order to obtain information not just from scientific journal articles, but also from reports, to supplement the very view papers on seagrass fisheries in Indonesia published in peer-reviewed national or international journals. This last search resulted in a total of 1,760 miscellaneous documents which were carefully screened to select information representative of all seagrass regions in Indonesia. Additional data regarding the presence of seagrass fisheries in their area and the fishing gear used were collected by interviewing some people who live or work in areas for which little or no data were found during the literature search to gain a broader picture of seagrass fisheries in Indonesia. All representative and selected documents were retained for further descriptive analysis.

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3. Results and discussion

3.1 Seagrass extent and distribution in Indonesia

The estimated extent of seagrass meadows in Indonesia is about 8,812.9 km² with a coastline length of 80,791 km [6], which is much lower than a previous estimation of about 30,000 km² of seagrass meadows throughout the Indonesia Archipelago [25]. Moreover, the Indonesian Institute for Science has been validating seagrass areas in Indonesia and has found an extent of about 2,934.64 km², which is 16% - 35% of the potential seagrass extent in this region [26]. The seagrass meadows are distributed along the coastline, surrounding some large and almost all small islands in Indonesia (Figure 1) [27].



Figure 1. Map of seagrass distribution in Indonesia (from [27]).

Seagrass are also distributed across all marine ecoregions in Indonesia; there are 12 marine ecoregions, a biogeographic classification for the world’s coastal and shelf areas determined based on their biological diversity, including seagrass diversity (Figure 2) [28,29]. Generally speaking, the distribution of seagrass meadows in all marine ecoregions shows the importance of this ecosystem for

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marine biodiversity as a whole and that seagrass meadows should be purposefully considered in the management and conservation of marine biodiversity.

Overlaying Figures 1 and 2 shows that the Lesser Sundas, the south-most marine ecoregion of Indonesia, is the ecoregion with the most extensive seagrass meadows. This ecoregion encompasses the Indonesian provinces of Bali, West Nusa Tenggara, East Nusa Tenggara, and part of southeast Maluku. Seagrass meadows within the Lesser Sundas ecoregion mostly occur in close association with fringing reefs, the most common reef type within the ecoregion, with total seagrass area in the shallow waters of this ecoregion estimated at 273 km² based on Landsat imagery [30]. The highest seagrass abundance in Indonesia is mostly associated with fringing reefs, as the fringing reefs dissipate the energy of incoming waves and create a protective environment in the back reef zone and coastal lagoons [31], resulting in a preferred habitat for most seagrass species to live [5].



Figure 2. Map of the twelve marine ecoregions in Indonesia where seagrasses are found (from [28]).

3.2 The importance of seagrass to fisheries in Indonesia

Seagrass meadows support fisheries through providing nursery habitat for fish stocks in adjacent and deepwater habitats, creating expansive fishery habitat rich in fauna, and providing trophic support to adjacent fisheries (Figure 3) [32]. Moreover, seagrass meadows also provide support by promoting the health of fisheries associated to connected habitats (e.g., coral reefs) [24], and as an important fishing ground for small-scale fisheries in shallow coastal tropical habitats, and can even support a larger fish catch volume compared to coral reef and mangrove ecosystems [33].

We assessed the diversity of fish and invertebrate species utilizing seagrass meadows in Indonesia by collating some studies on seagrass associated fauna in the Indonesian Archipelago (Table 1). The data show that seagrass meadows in many regions in Indonesia are occupied by highly diverse faunal communities, with many species that are important for fisheries. The high diversity of fishes and invertebrates found in seagrass beds is facilitated not only from the provision of habitat for living, shelter, and protection but also because the primary productivity of the seagrasses also serves as a basic energy source for the faunal communities [5].

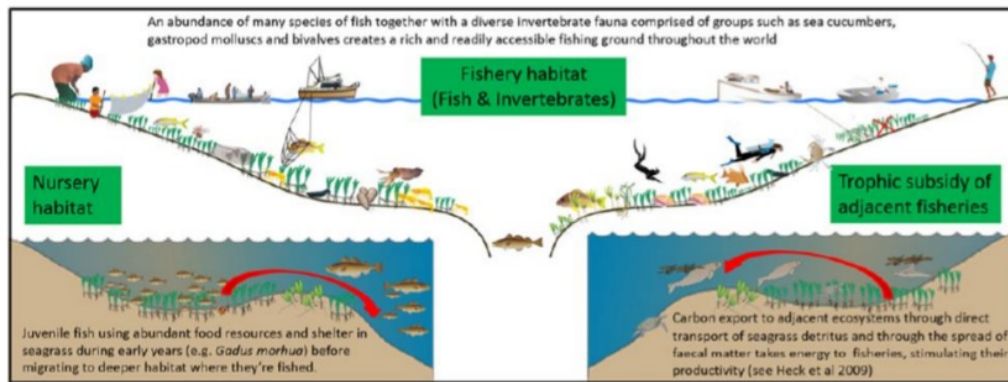


Figure 3. Seagrass meadows support food security through fishery through three key roles: as nursery habitat, fishery habitat, and trophic subsidy of adjacent fisheries (from [32]).

Table 1. Seagrass associated fauna in some seagrass meadows in Indonesia.

Seagrass Meadow Location (Extent)	Seagrass Ecosystem Goods	Refs.
East Coast of Bintan Island, Riau (seagrass area 25 km ²)	Fishes, swimming crabs, squids, and mollusks	[34]
Teluk Bakau, Bintan, Riau	Economically valuable species: 13 fishes, 2 crustaceans, 4 mollusks	[35]
Eastern Bintan (Berakit, Malang Rapat, Teluk Bakau), Riau (seagrass area 15,9 km ²)	Fishes, crustaceans, and mollusks	[36]
Seribu Islands, Jakarta	Holothurians and many other invertebrates	[37]
Banten Bay, Serang, Banten (seagrass area 3.3 km ²)	9 economically valuable fish species, squids, crabs, holothurians, and feeding ground for dugong	[38]
Teluk Ekas, Lombok Timur, West Nusa Tenggara	35 fish species	[39]
Barrang Lompo Island, Spermonde Archipelago, South Sulawesi (seagrass area 0.5 km ²)	28 fish species,	[40]
Bone Batang Island, Spermonde Archipelago, South Sulawesi	46 fish species, 38 invertebrate species	[41]
Kapopposang Island, Spermonde Archipelago, South Sulawesi	62 fish species	[42]
Wakatobi Marine National Park, South-West Sulawesi	81 fish species	[43]
Wori Sub-District, North Sulawesi	75 fish species	[44]
Tongkaina, Bunaken, North Sulawesi	10 fish species	[45]
Napomanuk Island, Western Likupang, North Minahasa, North Sulawesi	55 fish species	[46]

Seagrass Meadow Location (Extent)	Seagrass Ecosystem Goods	Refs.
Rap-Rap Reef, Wowantulap, South Minahasa, North Sulawesi (seagrass area 13 km ²)	A feeding ground for green turtle and dugong	[47]
Kotania Bay, Western Seram, Maluku (seagrass area 8.24 km ²)	35 seaweed species, 9 sea cucumber species, 6 species of economically important mollusks, 99 fish species, dugong and sea turtle	[48]
Tanjung Tiram, Teluk Ambon Dalam, Maluku	72 fish species	[50]
Laut Banda Marine Tourism Park, Maluku	20 fish species	[51]
Kei Besar Islands (South Kelapa Island, East Kelapa Island, West Kelapa Island, Karkarit, Tansos, Uwatrean), Southeast Maluku	56 fish species	[52]
Kei Kecil Islands, Southeast Maluku	103 species of mollusks (including 72 economically important species)	[53]
Sibu Island, Tidore, North Maluku	13 fish species	[54]
Youtefa Bay, Jayapura, Papua	79 fish species	[55]
Kornasoren and Yenburwo Villages, Numfor Island, Papua	fishes, molluscs, holothurians	[56]

3.3. Seagrass fisheries in Indonesia

The expression “seagrass fishery” refers to the capture of fish and invertebrates from the seagrass habitat [57]. Seagrass meadows in Indonesia are important as fishing grounds, and therefore seagrass fisheries in Indonesia definitely exist. For a long time, these fisheries were not well recognized, especially because the occurrence of seagrass beds in the fishing ground is mostly combined with adjacent or overlapping coral reefs so that the term “coral reef fishery” is far more popular [58]. In total, Indonesian seagrass fisheries have been estimated to be worth a minimum of approximately US\$230 million [14]. Some studies have been done to determine the economic benefits of seagrass fisheries in Indonesia, for example: (1) seagrass fisheries in East Bintan, Riau (with seagrass area 16 km²) were valued of US\$ 1,131,600 y⁻¹ [36], while the value of recreational fishing from the area was estimated at approximately IDR 351,179.56 h⁻¹ y⁻¹ [59]; (2) seagrass fisheries in Banten Bay (seagrass area 3.3 km²) were valued at IDR 712 million h⁻¹ y⁻¹ [60]; (3) in Wakatobi Marine National Park, Southeast Sulawesi, the contribution of seagrass to fisheries was estimated at an average of US\$77.9±40.4 h⁻¹ [14]; (4) in Kotania Bay, Western Seram, Maluku (seagrass area 8.24 km²), the catch was valued at IDR 30 – 44 million y⁻¹ per fisherman [48]; (5) the seagrass fisheries in Youtefa Bay, Jayapura, Papua, targeting fishes and invertebrates, were valued at about IDR39 million y⁻¹ per fisherman [55]; (6) the contribution of the seagrass meadows in the Derawan Islands, North Kalimantan to seagrass fisheries (fish and invertebrates) was estimated at US\$ 49,233.49 h⁻¹ y⁻¹ [61]. The distribution of fishing activity in seagrass beds is very extensive and occurs in all regions of Indonesia (Figure 4) [58].

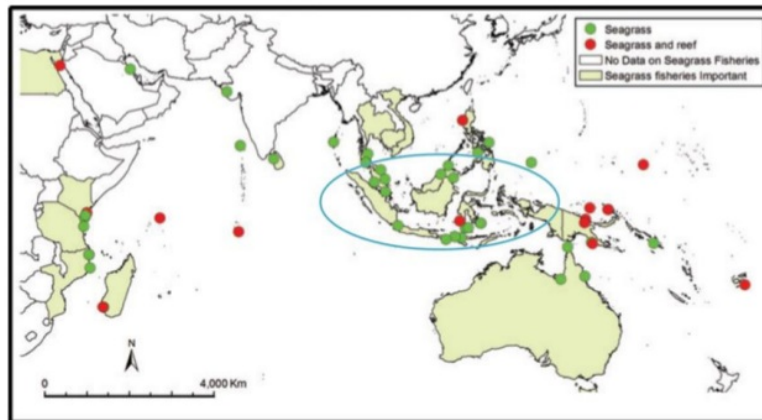


Figure 4. Map of seagrasses and seagrass fisheries (from [58]) illustrating the importance of these fisheries across the Indonesian archipelago.

Gleaning is a traditional fishing method (usually targeting invertebrates) conducted by just walking in seagrass beds during low tide and directly picking up the fauna from the substrate with bare hands or using simple tools. In Indonesia, several scientific studies on this practice have been published [32,35,39,48,55,56,62,63]. These gleaning fisheries are widely distributed across Indonesia, as shown by the map in Figure 5 [32]. Data from the literature on seagrass fisheries in different parts of Indonesia, including fishing methods, are shown in Table 2.

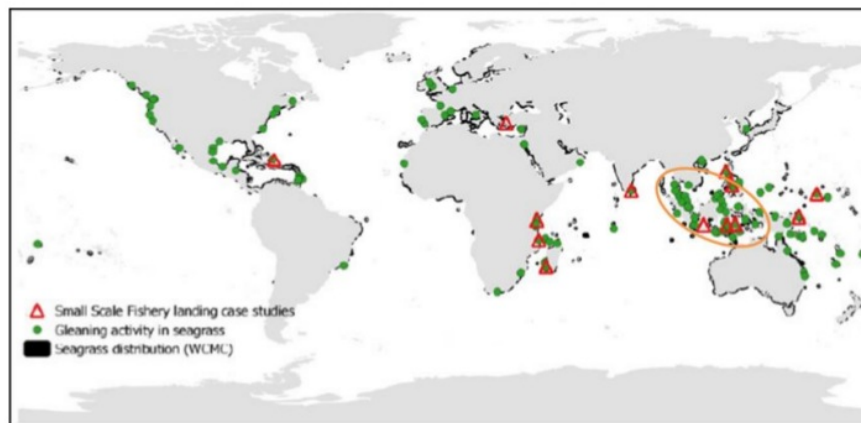


Figure 5. Map illustrating the wide distribution and high intensity of gleaning fisheries across the Indonesian archipelago (from [14]).

Table 2. Fishing methods used in the seagrass fisheries in Indonesia.

Region	Province	District	Island/Village	Fishing Method	Refs
Sumatera	Riau	Bintan	Malang Rapat, Bakau Bay, Berakit	nets, fishing rods, crab traps, tidal trap/"kelong karang", gleaning/"berkara ng"	[34,35]
Nusa Tenggara	Nusa Tenggara Barat	Sumbawa	Saleh Bay	tidal trap/"sero", traps, nets	[64]
Nusa Tenggara	Nusa Tenggara Barat	East Lombok	Tanjung Luar	gill nets, traps, trawl, gleaning	[65]
Java	Banten	Serang	Ekas Bay	Gleaning/"madak"	[39]
			Panjang Island	fishing rods, nets, traps	[38]
	Jakarta	Seribu Islands		fishing rods, nets, gleaning	[37]
Kalimantan	North Kalimantan	Derawan Islands		gill net, gleaning	[61]
Sulawesi	South Sulawesi	Selayar Islands	Benteng	"samba" nets, fishing rods, crab traps, gleaning, tidal trap/"sero"	[62,66]; pers.obs
			Bulukumba	Kampung Beru, Lemo-Lemo, Panrang Luhu, Kasuso	gleaning
		Sinjai	Sembilan Islands	seine net for siganids	[68]
Sulawesi	South Sulawesi	Takalar	Laikang	nets, traps, gleaning, "sero"	[62,69]
			Tanakeke Islands	nets, traps, push net for seahorse	pers.obs
	Southeast Sulawesi	Wakatobi	Hoga, Kaledupa	gill net, seine net, traps, gleaning	[14]
			Numana, Mandatti, Horuo, Mantigola	gleaning	[62]
			Sama Bahari, Mola, Wakatobi National Park	set net/"sero" gill net, traps, handlines, spearfishing, gleaning	[62] [70]
Maluku	North Maluku	Morotai Islands	Galo-Galo Island	gleaning	pers.com
			Rao Island	"sero"	pers.com
		Halmahera Tengah	South Weda (Leleo)	gill net and gleaning	[71]

Region	Province	District	Island/Village	Fishing Method	Refs
		Tidore	North Tidore (Maitara)	gillnet	[54]
		South Halmahera	West Gane (Sali)	gillnet	[54]
		Tidore Islands	North Oba (Sibu)	gillnet	[54]
		Seram	Kotania Bay	gill net, set net, traps, handline fishing, gleaning/"bameti"	[48]
Papua	Papua	Biak Numfor (Padaido, Aimando, Meosmanggu- andi)	Wundi, Sorina, Sokani Auki, Sandidori, Kanai Nusi Babaruk, Nusi Iranusdi Pai, Paidori, Imbeyomi Anobo, Sasari, Yeri, Mnupisen Meosmanguandi, Supraima	gillnet and gleaning gillnet and gleaning gillnet and gleaning gillnet and gleaning gillnet and gleaning gillnet and gleaning	18 pers.com pers.com pers.com pers.com pers.com pers.com pers.com pers.com pers.com pers.com
		Jayapura	Youtefa Bay	gillnet and gleaning	[55]

This preliminary study based on a search of the related literature shows that seagrass meadows in Indonesia are very important for the seagrass fisheries that occur in almost all nearshore seagrass areas across the Indonesian Archipelago, including the shallow waters around many small islands. These fisheries are small-scale multi-species and multi-gear fisheries employing many different kinds of fishing gear, including tidal traps (*sero*), fish traps, push nets, gill nets, fishing rods, spearfishing, and gleaning.

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