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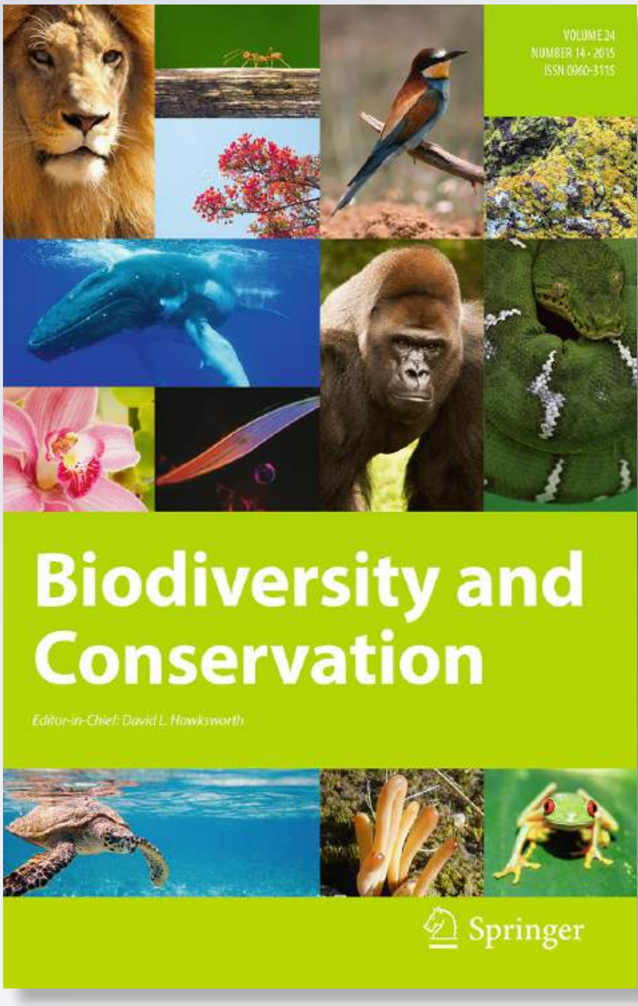

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ORIGINAL PAPER

Mangrove exploitation effects on biodiversity and ecosystem services

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Abstract Mangrove forests are one of the most important coastal ecosystems as they support many local communities. However, over the last two decades harvesting of mangrove forests has been extensive with effects on mangrove biodiversity and ecosystem services. We investigate the effect of mangrove harvesting on tree biodiversity in South Sulawesi, Indonesia. Using two line transects each in ten mangrove forests, mangrove composition, species dominance, density, frequency, coverage, and stem diameter and diversity were recorded. Interviews detailing provisioning ecosystem services were also conducted with local forestry and fishery workers to determine the level of exploitation. Ten mangrove species were recorded (*Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Nypa fruticans, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa,* and *Sonneratia alba*) belonging to six families (Avicenniaceae, Rhizophoraceae, Euphorbiaceae, Combretaceae, Arecaceae and Sonneratiaceae). Mangrove forests are now dominated by saplings and seedlings, with few trees above 15 cm diameter at breast height. *Rhizophora* sp. were found to be the most important and dominant species. *Rhizophora* sp. was the most widely used as it was deemed the most suitable for firewood and charcoal. In addition, it is the main species planted in mangrove restoration projects, which have focused on establishing production forest rather than

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restoring natural species composition and structure. Despite the decrease in biodiversity, the mangroves still provide a wide range of ecosystem services to the communities in the area.

Keywords Mangrove forests · Biodiversity · Ecosystem service · Indonesia · Sulawesi

Introduction

Mangrove forests provide a wide range of services and products for coastal communities including protection from storms, large waves (Danielsen et al. 2005), coastal erosion and pollutants, as well as nursery, feeding, and spawning grounds, fuel wood, charcoal, medicine, and timber (Chang-yi et al. 1997; Wang et al. 2003, Giesen et al. 2007; Ong and Gong 2013). They are found in tropical and subtropical coastal regions, approximately between 30°N and 30°S (Giri et al. 2010) and are dominated by trees and shrubs adapted to tidal areas (Tomlinson 1986; Wightman 1989). They are particularly common in sheltered coastlines, lagoons and estuaries that are flooded at high tide and free from inundation at low tide (Nybakken and Bertness 2004). With eighty percent of all true mangrove species, the most highest mangrove species diversity in the world is found in the Indo-Pacific region (Saenger et al. 1983). Indonesia alone contains 72 % of the world's true mangroves (Kusmana 1993) and has the highest mangrove diversity in the world.

The high value of mangrove forests has generated high levels of exploitation and deforestation which is reducing mangrove forest productivity globally (Duke et al. 2007). In 2005, the global area of mangrove forests was about 15.2 million ha, representing a loss of 3.6 million ha during the previous 25 years (FAO 2007). Indonesia lost 1.2 million ha in the same period, or about one quarter of the mangrove area, with only 3.2 million ha of mangrove forest remaining (Bakosurtanal 2009).

Besides permanent deforestation, the exploitation often changes the biodiversity of remaining mangrove forests, reducing the number and abundance of species, and changing the species composition and structure. Walters (2005) reported that wood cutting in mangroves in the Philippines created a change in forest structure and altered species

Table 1 Distribution and change of true mangrove species on the main islands of Indonesia

No.	Location	Period of study	Number of species	Change	References
1	Java Island	1993	28	−18	Kusmana (1993)
		2006	10		Suryono (2006)
[illegible]	Sumatra Island	1993	27	−10	Kusmana (1993)
		2008	17		Onrizal and Kusmana (2008)
3	Kalimantan Island	1993	25	−11	Kusmana (1993)
		2012	14		Ardiansyah et al. (2012)
4	Sulawesi Island	1993	27	−9	Kusmana (1993)
		1994	18		Nurkin (1994)
5	Maluku Island	1993	28	0	Kusmana (1993)
		2012	28		CRITC-PPO LIPI (2012)
6	Papua Island	1993	29	−16	Kusmana (1993)
		2003	13		Kusmana et al. (2003)

composition. In addition, reduced mangrove biodiversity has also been reported in Cameroon (Din et al. 2008) and Bangladesh (Iftekhar and Takama 2008) due to forest harvesting and several studies in Indonesia also document reduced diversity in mangrove forests. Collection of firewood and charcoal production on the east coast of North Sumatra led to decreasing mangrove areas, and forests were dominated by seedlings and saplings with few mature trees (Onrizal and Kusmana 2008). Similarly, in the Segara Anakan Lagoon, Central Java, wood cutting and high sedimentation rates from rivers inhibited the growth of some mangrove species (*Sonneratia* sp.*, Rhizophora* sp. and *Bruguiera* sp.) (Hinrichs et al. 2008). In the same area, the mangrove area had been reduced by about 23,000 ha between 1930 and 1996 and changes in species composition, structure of population and distribution pattern were observed (Suryono 2006). Overall, there has been a decrease in the number of mangrove species in all the main islands of Indonesia except the Maluku Islands (where no expansion in aquaculture has been observed), as seen in Table 1.

There are indications that reduced biodiversity of ecosystems may negatively affect a range of provisioning, regulating, cultural and supporting ecosystem services (Millennium Ecosystem Assessment 2005; Harrison et al. 2014). Costanza et al. (2006) went so far as to propose that a change of 1 % of the species composition will result in a change of 0.5 % of

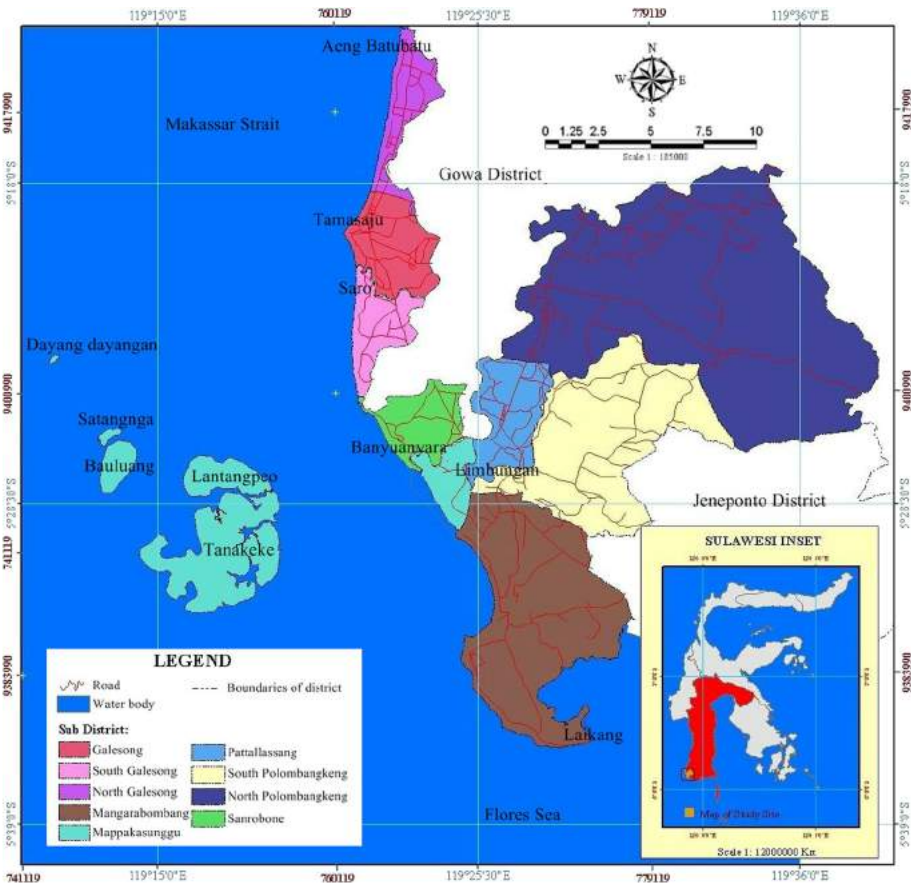

Fig. 1 Map of the Takalar district study area, South Sulawesi

the ecosystem services value, and Benayas et al. (2009) suggested that increasing biodiversity by 44 % will increase ecosystem services by 25 %. However, as Harrison et al. (2014) point out, there is a need for a more solid knowledge base on the linkages between biodiversity and ecosystem services, including analysis of more case studies where longitudinal changes can be observed. It is not clear whether high biodiversity is required for sustaining a high level of ecosystem services or whether most of the ecosystem services can be provided by low diversity (Cameron 2002; Mertz et al. 2007).

We investigated the effects of mangrove exploitation on biodiversity and relate this to changes in ecosystem services in one of the hotspots of mangrove exploitation in Indonesia, South Sulawesi; an area that has not been subject to many studies previously. In particular, we are interested in understanding whether changes in biodiversity have affected the supply of provisioning ecosystem services, such as firewood, timber, charcoal, *Nypa* palm leaves, fish, crabs and shrimps. We use transects to assess current tree diversity and use historical data and interviews to assess the impact of changes in diversity on ecosystem services.

Study area

The field work was conducted in Indonesia, the Takalar District, South Sulawesi, one of the most mangrove rich regions. These forests are under strong pressure from anthropogenic exploitation. The area is located between latitude 5°12′–5°38′ and longitude 119°10′–119°39′ (Fig. 1), about 45 km from the capital of South Sulawesi, Makassar City. The district covers 566,5 km^2 and is divided into nine sub-districts (Galesong, South Galesong, North Galesong, Mangarabombang, Mappakasunggu, Pattalassang, South Polombangkeng, North Polombangkeng and Sanrobone). Mappakasunggu consists of a mainland part and some small islands (Tanakeke, Lantangpeo, Bauluang, Satangnga and Dayang dayangan). The population is 272,316 persons with a population density of 481 persons per km^2 (BPS-Kab. Takalar 2012). The district has a coastline of 74 km (Ukkas 2001) characterized by mangrove, coral reefs, sea grass, sandy beaches, rocky beaches, estuaries, ponds, rice fields, and both residential areas and areas of tourism interest (BPS-Kab. Takalar 2012).

In this study, ten sampling sites were selected covering mangrove in mainland (villages of Laikang, Limbungan, Banyuanyara, Saro', Tamasaju, and Aeng Batubatu) and small islands (Lantangpeo, Tanekeke, Bauluang and Satangnga). The sampling sites were chosen due to increasing collection of wood by local communities and because mangrove restoration projects involving local communities, government and NGOs have been conducted. Mangroves on the mainland are most commonly distributed along the coasts, except for riverine mangrove forest in Limbungan village. The exploitation of mangroves is mainly for firewood, but in some sites (Tanakeke Island and Banyuanyara villages), aquaculture expansion is the dominant activity and in Limbungan village, collection of *Nypa* palm for handicrafts is more important. In the small islands, mostly thin strips of mangrove are found along the coast for wave protection whereas the inner parts of the mangrove areas generally have been degraded, converted to aquaculture ponds or felled for fuelwood, charcoal production and trade. The environmental characteristics of the mangroves in the study sites are similar. Bahar (2004) showed similar salinity in the sites of the present study (Tanakeke and Lantangpeo 27–31.5 ppt, Bauluang 29–30 ppt and Satangnga 30–33 ppt) and Tahir (2000) reported that the semi-diurnal tides reach 1.5 m (0.3–0.4 m above normal sea level) at high tide and 0.1–0.2 m at low tide in all islands.

Materials and methods

The biodiversity of mangrove forests including species composition and structure, was measured using a compass, clinometers, measuring tape, a tally counter, plastic rope, a tally sheet, and a reference book for identifying mangrove species.

The data were collected in August 2012 using the line transect method (English et al. 1997; Frontier Madagascar 2005; Simon 2007). This method is standard for estimating species composition and dominance, diversity, tree density, frequency, coverage, and stem diameter in sample plots located on a line drawn through the mangrove forest.

We implemented two line transects per site, the length depending on the thickness of the mangrove forest from the seaward edge to the landward margin. Each starting and end point of the transects and zone boundaries was marked by GPS (Global Positioning System) (English et al. 1997; Frontier Madagascar 2005; Simon 2007). We used 90 m line transects for sites III (Bauluang Island), V (Laikang Village), VI (Limbungan Village), VII (Banyuanyara Village), VIII (Saro' Village), IX (Tamasaju Village), and X (Aeng Batu-batu Village), and 50 m line transects for sites I (Lantangpeo Island), II (Tanakeke Island), and IV (Satangnga Island). On each line transect, we established three terraced plots using measuring tape and plastic ropes. On the 90 m line transect, the plots were 30 m apart and on the 50 m line transect, they were 10 m apart. The size of each plot was 10 m × 10 m for tree level, 5 m × 5 m for sapling level, and 2 m × 2 m for seedling level (Fig. 2).

Furthermore, we recorded the species name and individual number of mangrove trees, saplings, and seedlings found in each plot and measured the diameter at breast height (DBH) of the stems (English et al. 1997; Frontier Madagascar 2005; Simon 2007).

Data on provisioning ecosystem services including forestry products (firewood, charcoal, and *Nypa* palm craft) and fisheries products (fish, crab and shrimp capture, and aquaculture) were obtained from households who live around mangrove areas based on a household survey undertaken in ten areas of Takalar district in South Sulawesi. Questionnaires were administered to 100 households, who were selected by a Purposive Sampling method. Information was collected on the respondents' understanding of: (a) mangrove functions and benefits, (b) details of their use of mangrove forests, such as forest type and age as well as frequency of use, (c) the amount earned per utilization and the operation costs involved. Further details and the reporting of these results are found in Malik et al. (in review) and in Malik et al. (2015).

Data analysis

The species density, relative density, species frequency, relative frequency, and species coverage and relative coverage were calculated by the formulas 1–6: (Curtis and McIntosh 1950)

$$\mathrm{Di} = \frac{\mathrm{ni}}{\mathrm{A}}, \tag{1}$$

and

$$\mathrm{RDi} = \frac{\mathrm{ni}}{\sum \mathrm{n}} \times 100\,\% \tag{2}$$

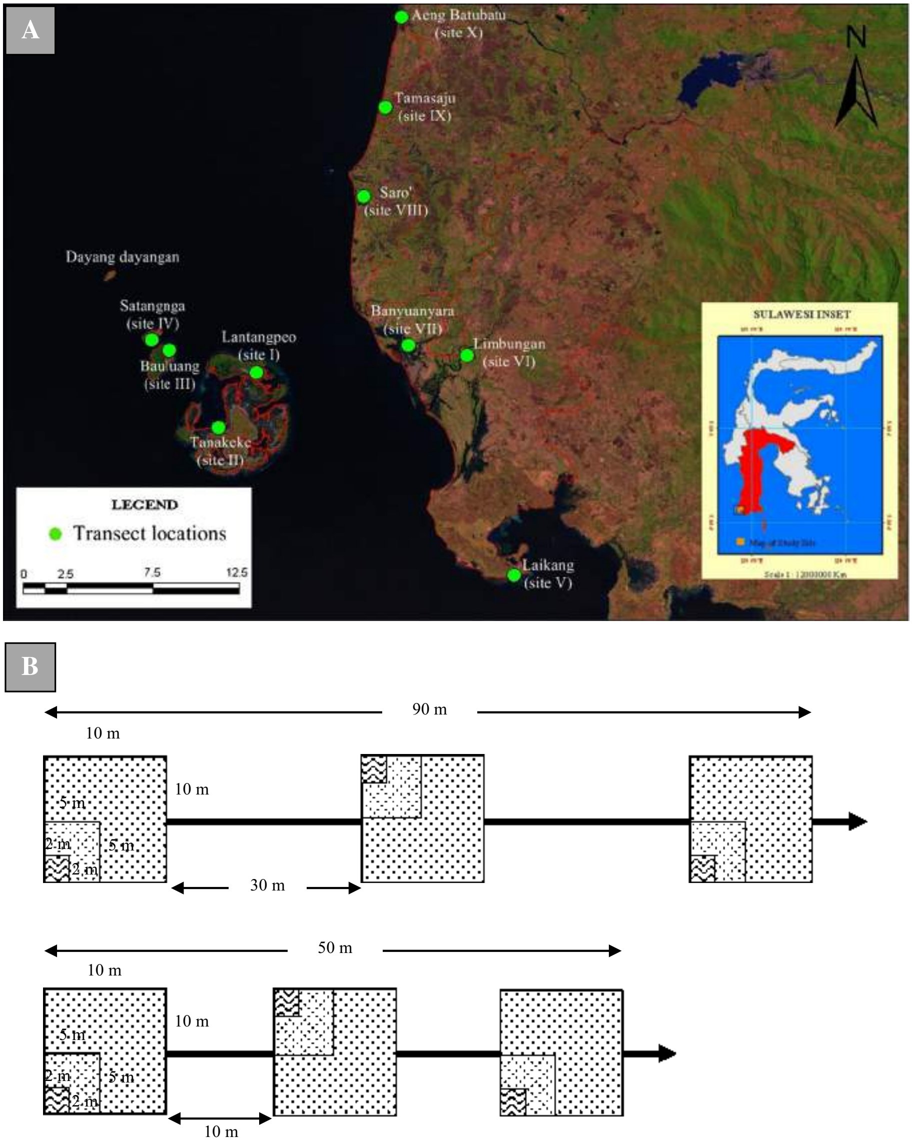

Fig. 2 **a** Locations of transect measurements. **b** Design of the *line plots* applied to each transect

where Di is the density of species i (individual/ha), RDi is the relative density of species i (%), ni is the number of counts per species i, Σn is the total number of counts for all species, A is the total area of the sample observed (ha)

$$\mathrm{Fi} = \frac{\mathrm{Pi}}{\sum \mathrm{p}}, \tag{3}$$

and

$$\mathrm{RFi} = \frac{\mathrm{Fi}}{\sum \mathrm{F}} \times 100\,\% \tag{4}$$

where Fi is the frequency of species i, RFi is the relative frequency of species i (%), pi is the number of plots where species i occurs, ΣF is the total number of occurences for all species, Σp is the total number of plots observed

$$\mathrm{Ci} = \frac{\mathrm{BA}}{\mathrm{A}}, \tag{5}$$

and

$$\mathrm{RCi} = \frac{\mathrm{Ci}}{\sum \mathrm{C}} \times 100\,\% \tag{6}$$

where Ci is the areal coverage for species i, BA is the $\pi \mathrm{DBH}^2/4$, where BA is the basal area (cm) and DBH is the diameter at breast height (cm), A is the total area of plot (m^2), ΣC is the total area coverage for all species, RCi is the relative coverage of species i (%).

The importance value index (IVI) was calculated by the sum of relative density, relative frequency, and relative coverage to express the dominance level of individual mangrove species (formula 7): (Curtis 1959)

$$\mathrm{IVI} = \mathrm{RD} + \mathrm{RF} + \mathrm{RC}; \tag{7}$$

the range of IVI = 0–300.

The diversity index (D) of mangrove species was calculated by the actual number of different species and total number of individuals (formula 8):

$$\mathrm{D} = \sum \frac{\mathrm{ni}}{\mathrm{N}}; \tag{8}$$

the range of D = 0–1 (0 = no diversity; 1 = high diversity)where ni is the number of different species in the area, N is the number of individuals in the area.

Results

Composition and dominance

A total of 1850 mangrove trees were recorded, comprising mature trees (27 %), saplings (40 %) and seedlings (33 %) (Table 2). Ten mangrove species were recorded (*Avicennia alba, Bruguiera gymnorrhiza, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa,*

Table 2 Number of individual mangrove counts recorded

Growth level	Sampling site										Sub total	%
	I	II	III	IV	V	VI	VII	VII	IX	X		
Tree	44	79	37	83	0	58	63	27	48	69	508	27
Sapling	196	86	128	25	63	23	69	60	35	53	738	40
Seedling	49	48	42	38	23	36	102	112	39	115	604	33
Total	289	213	207	146	86	117	234	199	122	237	1850	100

Table 3 List of mangrove species recorded

No.	Name of family	Name of species	Local name	Sampling site									
				I	II	III	IV	V	VI	VII	VIII	IX	X
1	Avicenniaceae	*Avicennia alba*	*Api-api*	+	+	+	+	−	−	−	+	−	+
2	Rhizophoraceae	*Bruguiera gymnorrhiza*	*Tanjang*	−	−	−	−	−	+	+	+	+	+
3	Rhizophoraceae	*Ceriops tagal*	*Tengar*	−	−	−	+	−	−	+	+	−	−
4	Euphorbiaceae	*Excoecaria agallocha*	*Buta-buta*	−	−	−	−	−	−	+	−	+	−
5	Combretaceae	*Lumnitzera racemosa*	*Api-api balah*	−	−	−	−	−	−	−	+	−	+
6	Arecaceae	*Nypa fruticans*	*Nipa*	−	−	−	−	−	+	−	−	−	−
7	Rhizophoraceae	*Rhizophora apiculata*	*Bakau*	+	+	+	−	−	+	+	−	−	−
8	Rhizophoraceae	*Rhizophora mucronata*	*Bakau*	+	+	+	+	+	+	+	+	+	+
9	Rhizophoraceae	*Rhizophora stylosa*	*Bakau*	−	+	−	−	+	−	−	−	−	+
10	Sonneratiaceae	*Sonneratia alba*	*Pedada*	+	+	+	−	−	−	+	+	−	+
Number of species=				4	5	4	3	2	4	6	6	3	6

+ Present, − not present

Nypa fruticans, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa and *Sonneratia alba*), belonging to six families (Avicenniaceae, Rhizophoraceae, Euphorbiaceae, Combretaceae, Arecaceae, and Sonneratiaceae).

At each sampling site, two to six species were recorded, with sites VII, VIII, and X having the highest number of species. *Rhizophora mucronata* grows by the seaside and was found at all sites, whereas *Nypa fruticans* was only found in the riverine site VI as the palm is only suited for this environment. At site V, only two mangrove species were found as this area has been subjected to mangrove restoration (Table 3).

The density of *Rhizophora mucronata* made this species dominant in all growth stages, followed by *Rhizophora stylosa* for mature trees, *Rhizophora apiculata* for saplings, and *Bruguiera gymnorrhiza* for seedlings. The frequency was also dominated by *Rhizophora mucronata* at all levels of regeneration, followed by *Rhizophora stylosa, Avicennia alba*, and *Sonneratia alba*. Finally, the coverage is also dominated by *Rhizophora mucronata*, followed by *Sonneratia alba*.

Rhizophora mucronata was the dominating species at all levels of regeneration, followed by *Sonneratia alba*, whereas for saplings and seedlings, *Rhizophora apiculata* and *Avicennia alba* dominated, respectively (IVI, Table 4).

Mangrove species diversity

Diversity values of mangrove species at tree level were between 0.04 and 0.22, whereas for saplings they were between 0.02 and 0.17 and for seedlings, between 0.05 and 0.11. The highest diversity for trees was found at site VIII, whereas for saplings it was found at site VI and for seedlings at sites VI (Table 5). However, the diversity values of mangrove at all growth stages and sites were very low.

Table 4 Importance value index (IVI) of mangrove species

No.	Tree Mangrove species	D	RD	F	RF	C	RC	IVI	Rank
1	*Avicennia alba*	0.0103	6	0.367	13	0.9575	15	35	III
2	*Bruguiera gymnorrhiza*	0.0087	5	0.1	4	0.7163	11	20	VI
3	*Ceriops tagal*	0.007	4	0.167	6	0.3464	6	16	VII
4	*Excocaeria agallocha*	0.0047	3	0.067	2	0.216	3	9	X
5	*Lumnitzera racemosa*	0.0033	2	0.067	2	0.3191	5	10	IX
6	*Nypa fruticans*	0.0157	9	0.067	2	0.0734	1	13	VIII
7	*Rhizophora apiculata*	0.016	9	0.367	13	0.6738	11	34	IV
8	*Rhizophora mucronata*	0.076	45	0.8	29	1.3241	21	95	I
9	*Rhizophora stylosa*	0.0163	10	0.367	13	0.4972	8	31	V
10	*Sonneratia alba*	0.0113	7	0.367	13	1.1416	18	38	II
Total		0.1693	100	2.733	100	6.2654	100	300	

No.	Sapling	D	RD	F	RF	IVI	Rank
1	*Avicennia alba*	0.0183	7	0.367	13	21	IV
2	*Bruguiera gymnorrhiza*	0.0197	8	0.1	4	12	VI
3	*Ceriops tagal*	0.009	4	0.167	6	10	VII
4	*Excocaeria agallocha*	0.0063	3	0.067	2	5	IX
5	*Lumnitzera racemosa*	0.0067	3	0.067	2	5	VIII
6	*Nypa fruticans*	0.0027	1	0.067	2	4	X
7	*Rhizophora apiculata*	0.0483	20	0.367	13	33	II
8	*Rhizophora mucronata*	0.091	37	0.8	29	66	I
9	*Rhizophora stylosa*	0.018	7	0.367	13	21	V
10	*Sonneratia alba*	0.026	11	0.367	13	24	III
Total		0.246	100	2.733	100	200	

No.	Seedling	D	RD	F	RF	IVI	Rank
1	*Avicennia alba*	0.0243	12	0.367	13	26	II
2	*Bruguiera gymnorrhiza*	0.026	13	0.1	4	17	VI
3	*Ceriops tagal*	0.0137	7	0.167	6	13	VII
4	*Excocaeria agallocha*	0.0087	4	0.067	2	7	VIII
5	*Lumnitzera racemosa*	0.006	3	0.067	2	5	IX
6	*Nypa fruticans*	0.004	2	0.067	2	4	X
7	*Rhizophora apiculata*	0.0237	12	0.367	13	25	III
8	*Rhizophora mucronata*	0.0603	30	0.8	29	59	I
9	*Rhizophora stylosa*	0.0123	6	0.367	13	20	V
10	*Sonneratia alba*	0.0223	11	0.367	13	25	IV
Total		0.2013	100	2.733	100	200	

D Density, *RD* relative density, *F* frequency, *RF* relative frequency, *C* coverage, *RC* relative coverage, *IVI* importance value index

Table 5 Diversity index (D) of mangrove forest

Growth level	Index	Sampling site									
		I	II	III	IV	V	VI	VII	VIII	IX	X
Tree	D	0.09	0.06	0.11	0.04	–	0.07	0.10	0.22	0.06	0.09
Sapling	D	0.02	0.06	0.03	0.12	0.03	0.17	0.09	0.10	0.09	0.11
Seedling	D	0.08	0.10	0.10	0.08	0.09	0.11	0.06	0.05	0.08	0.05

Frequency distribution of diameter size classes for all mangrove species

The DBH of mangrove trees was between 6 and 24 cm. The diameter size classes of 10–15 cm dominated, followed by 15–20 cm. *Rhizophora mucronata* had the highest frequency in the diameter classes 10–15, 15–20, and <10 cm, whereas *Rhizophora stylosa* had the highest frequency in diameter classes of more than 20 cm. All mangrove species (10 in total) were represented in the 10–15 cm diameter size class and eight species were found in the 15–20 cm diameter size class (Fig. 3).

Discussion

Comparison of the species composition of mangroves in the study area with the total of 27 mangrove species in Sulawesi Island (Kusmana 1993), 43 in Indonesia (Kusmana 1993), and 60 species worldwide (Saenger et al. 1983), indicates that 37, 23 and 17 %, respectively, of the total true mangrove species known are present in this case area.

In a similar area in South Sulawesi, Nurkin (1994) recorded 18 species in the early 1990s indicating that there has been a reduction in the number of species over the past two decades. Four of the ten species found in the present study area (*Avicennia alba, Excoecaria agallocha, Lumnitzera racemosa,* and *Rhizophora stylosa*) were not recorded by Nurkin (1994). By contrast, 12 species recorded by Nurkin (1994) (*Acanthus ilicifolius*, *Acrostichum aureum*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera parviflora*, *Heritiera littoralis, Lumnitzera littorea, Scyphiphora hydrophyllacea*, *Sonneratia acida*, *Sonneratia ovata*, *Xylocarpus granatum*, and *Xylocarpus moluccensis*) were not found in the present study.

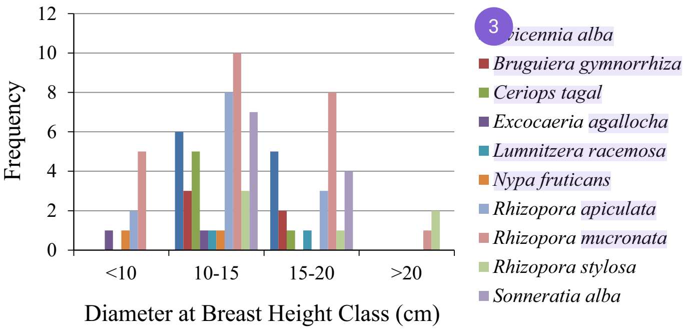

Fig. 3 Frequency distribution of diameter size classes of mangrove species

Furthermore, the number of true mangrove species was less than those recorded from a number of other sites in Southeast Asia. These include Balok River Pahang of Malaysia with 12 species (Rozainah and Mohamad 2006), 17 species in the east coast of North Sumatra (Onrizal and Kusmana 2008), Aurora, Philippines with 18 species (Rotaquio et al. 2007), Sundarbans Delta, Eastern India with 24 species (Barik and Chowdhury 2014), and Segara Anakan Lagoon in Central Java of Indonesia with 26 species (Hinrichs et al. 2008).

In addition to the generally low number of species, there was also a clear dominance of one or two species, especially *Rhizophora* sp., which could indicate instability of the ecosystem (Krebs 1989). Stable ecosystems occur as the species population density tends towards equilibrium after a disturbance and no one species becomes dominant. The relative density, frequency, and coverage of mangroves were all below 50 % (Table 4), indicating that there are large areas of open forest and that the rate of biodiversity of species is declining. Due to regeneration, mangrove composition was dominated by saplings and seedlings, followed by mature trees with DBH dominance between 10 and 15 cm and it was hard to find mature mangrove. This pattern is similar to what occurred on the east coast of North Sumatra, where charcoal production and development of aquaculture caused mangrove deforestation and degradation. Today, mangroves of this area are regenerating (in the area of former ponds) and were recorded mostly to consist of saplings and seedlings, whereas mature trees were much less frequent (Onrizal and Kusmana 2008).

The disturbance has primarily been caused by the expansion of aquaculture, whereby patches of mangrove forest are clear-cut and secondly by degradation of forests through timber harvesting and collection of firewood for charcoal production, see Fig. 4a, b (Malik et al. in review). The conversion of mangrove forest to aquaculture has increased in past decades in several sites within the study area and in 2012 reached 77 % of the total mangrove area, with an annual expansion of 5 % from 1979 to 1996. The expansion of aquaculture has mainly taken place in Tanakeke Island and Banyuanyara village, whereas wood cutting activities have increased in all areas and primarily in Lantangpeo and Satangnga Islands (Fig. 4a) (Malik et al. in review). The local population prefers to cut *Rhizophora* sp. trees when they have a length of at least 4 m and a diameter of 4–8 cm (Fig. 4b) (Malik et al. in review). They favor this species for firewood as it is more durable when burned at a high temperature, produces low emissions of smoke, has a fragrant aroma, and is more profitable when marketed than other types of firewood (Nurkin 1994; Weinstock 1994; Malik et al. in review). Thus, the proportion of individual *Rhizophora* sp.

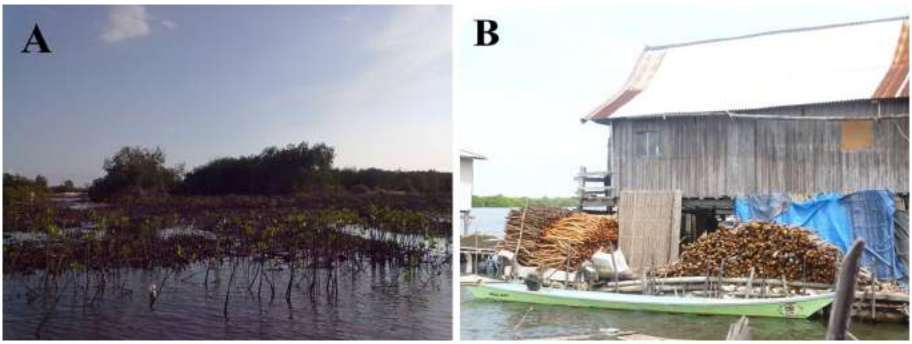

Fig. 4 **a** Mangrove area destruction caused by wood cutting in Satangnga Island and **b** firewood production of *Rhizophora* sp. in Lantangpeo Island

trees with a diameter of (4–8 cm) is lower (Fig. 3), whereas the other sizes prove that the trees regenerate successfully. The fact that people are very selective with regard to which species they use and the desirable sizes of the trees is similar to what was found by Walters (2005) in the Philippines, where preferences for *Rhizophora* sp. including *Rhizophora mucronata* were also recorded.

In general, the dominance of *Rhizophora* sp. is similar to other areas in Southeast Asia, such as Sundarbands Delta, Balok River Pahang, Matang in Malaysia, and Segara Anakan Lagoon in Central Java, Indonesia. Out of 24 true mangrove species that were measured in the Indian Sundarban Delta, the highest number of species belonging to the Rhizophoraceae family is found (nine species, including *Rhizophora mucronata* and *Rhizophora apiculata*) (Barik and Chowdhury 2014). Giri et al. 2014 reported that the inner part of the mangrove forest in Indian Sundarban is dominated by *Rhizophora* sp., *Excoecaria* sp., and *Bruguiera* sp. The communities who are living around the delta have been using these species for tannin, fuelwood, and timber, and their leaves as medicines such as *Rhizophora mucronata* for angina, *Bruguiera gymnorrhiza* for diarrhea and blood pressure, and *Excoecaria agallocha* for leprosy (Frost 2010). In Balok River Pahang, *Rhizophora apiculata* was the most common, with the highest density and IVI, followed by *Rhizophora mucronata* (Rozainah and Mohamad 2006). Similarly, the 40,000 hectares of mangrove forest in Matang, Malaysia, are dominated by *Rhizophora apiculata* (Ong 1982), whereas in Segara Anakan Lagoon, dominance is shared between *Rhizophora apiculata*, *Aegiceras corniculatum*, and *Nypa Fruticans* (Hinrichs et al. 2008). In these three areas, *Rhizophora* sp. is mainly used for fuelwood and charcoal production by communities for domestic and commercial purposes. In addition, they also use tree bark from *Rhizophora* sp. as medicine to cure diarrhea and stop hemorrhages, whereas the leaves, buds, fruits, and seedlings (propagules) of some *Rhizophora* sp. have been used for food consumption (Rozainah and Mohamad 2006; Jusoff and Taha 2008; Sastranegara et al. 2007). Contrary to this, the east coast of North Sumatra and Aurora, Philippines, are dominated by *Avicennia marina*. (Onrizal and Kusmana 2008; Rotaquio et al. 2007), but *Rhizphora* sp. is still one of the most utilized species for firewood and charcoal production (Onrizal and Kusmana 2008; Primavera 2000).

The many uses of *Rhizophora* sp. also make it the favored species for restoration of mangrove forests indicating that while mangrove restoration is mainly argued from a conservation point of view, the choice of species has clear economic aims; essentially, a production forest is created, as has also been reported by Weinstock (1994). Thus, most mangrove restoration projects implemented by governments and NGOs that also involved local communities in Southeast Asian countries have mainly focused on planting one or two species and very often using monocultures of *Rhizophora* sp. (Gan 1995; Ellison 2000; Primavera and Esteban 2008). It is therefore clear that with its fast regeneration and by being favored for restoration, this species will continue to dominate in the future.

Despite mangroves having been deforested and degraded in South Sulawesi with a decline in biodiversity as the result, mangrove forests still provide ecosystem services that are critical to local livelihoods. Communities still benefit from mangroves in the form of forestry products (firewood, charcoal production, and *Nypa* palm crafting) and fisheries products (fish, shrimp, crab, and aquaculture). For instance, in Lantangpeo and Satangnga Island areas, where less diverse mangroves exist mainly due to wood cutting practices, communities still benefit from household consumption and sale of firewood and charcoal. On a monthly basis, a household can collect an average of five bundles (1 bundle = 100 stems and 1 stem = 1 meter) of firewood (primarily from *Rhizophora* sp.), providing an average income of USD 42, whereas a charcoal producer can produce 500 kg per month, corresponding to an average income of about USD 300. In Limbungan Village, where *Nypa* palm leaves are collected for crafting of hats, roofs, walls, floor mats, and baskets, they can gather leaves (up to 100 bundles per operation; 1–2 times per month), yielding an income of up to USD 300 per month (Malik et al. in review). In Tanakeke Island and Banyuanyara Village, where mangroves have been removed mainly due to conversion to aquaculture, a thin belt of mangrove trees are still left on the outside of the ponds and borders of the sea to protect the ponds from abrasion (Malik et al. in review). Overall, fish, crab, and shrimp capture per household of fishermen were 2450, 338, and 213 kg/year, respectively, and the studied households claimed that this is a decrease compared to the past (Malik et al., in review). However, this decrease may be because households focus their activities on shrimp production from aquaculture ponds, which have increased both farmers' income and state revenue and have provided new opportunities for alternative employment for communities (Malik et al. in review). This suggests that the mangroves still perform essential ecosystem functions and thereby that degradation, expressed here as lower biodiversity, does not seem to affect ecosystem services. We acknowledge that a comparison with the ecosystem services provided by undisturbed mangrove could have been useful to assess the impact of degradation against a 'control forest', but this was not possible in the study area, where all mangrove forests have been disturbed.

Conclusion

This paper has explored the effects of mangrove exploitation on the biodiversity of mangrove forest in South Sulawesi. The study included species composition, species dominance, diversity, tree density, frequency, coverage, the diameter of stems, as well as the subsequent relationship to ecosystem services. High dependence on and varied utilization of mangrove forests by communities in past decades have led to a decrease in biodiversity. *Rhizophora* sp. is the predominant species and also the one most commonly exploited by local communities because it yields greater economic benefits than other species. In an effort to further exploit the mangrove forest, projects that involve communities, government, and NGOs have widely replanted *Rhizophora* sp. Mangrove restoration projects have so far focused on a low diversity of species to satisfy forest production and economic interests. Nonetheless, despite the observed deterioration in biodiversity, the mangrove habitat in South Sulawesi is still able to deliver provisioning ecosystem services and social and economic benefits to the communities and state.

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