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Floristic composition of mangrove community in Ngurah Rai Forest Park and Nusa Lembongan, Bali, Indonesia

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Abstract. *Wijaya IMS, Sugiana IP, Astarini IA, Ginantra IK, Rahim KAA. 2024. Floristic composition of mangrove community in Ngurah Rai Forest Park and Nusa Lembongan, Bali - Indonesia. Biodiversitas 25: 300-309.* The floristic composition of mangroves can be influenced by various factors, one of which is the size of the island. Ngurah Rai Forest Park is one of the mangrove areas in the mainland of Bali, while Nusa Lembongan on the southeastern mainland represents the mangroves on the small island. This research aimed to study the floristic composition of the mangrove species in these areas based on the diversity and the community structure. A total of 20 true mangrove species were found in these mangrove areas, with 18 species in Ngurah Rai Forest Park and 15 species in Nusa Lembongan. The mangrove community structure comprises *Sonneratia alba* and *Rhizophora* (*R. apiculata*, *R. mucronata*, and *R. stylosa*). *S. alba* has more impact in relative dominancy, while the *Rhizophora* has more impact in relative density. This study reports moderate diversity based on the Shannon-Wiener Index in both locations in all growth forms (trees, saplings, and seedlings). The Index of Dominance and Index of Evenness indicate the mangrove community is in stable condition with no extremely dominated species and fairly even species distribution. The mangrove condition is categorized as Good with Dense Trees based on the Decree of the Minister of Environment number 201 of 2004.

Keywords: Community structure, mangrove vegetation, small island mangrove

INTRODUCTION

Mangroves are an important coastal ecosystem that indirectly supports the ecosystem function of land and sea in various ways (Carugati et al. 2018; Twilley 2019). Mangroves can act as a sediment trap by its massive root arrangement to prevent coral damage from the increasing water turbidity (Azman et al. 2021; Wang and Gu 2021). At the same time, by accumulating the sediment, seawater intrusion can be avoided since the distance between the mainland and the ocean has become wider, so the soil and groundwater parameters can be maintained (Gilman et al. 2006; Veitayaki et al. 2017). Mangrove also plays a vital role as a nursery ground for marine biotas by providing a suitable habitat to spawn, feed, and protect (Veitayaki et al. 2017; Cravo et al. 2021; Arifanti et al. 2022). Even a small mangrove system significantly affects many fish species that spend their juvenile phases in the mangrove (Cravo et al. 2021).

Mangroves have limited distribution on earth. The center of mangrove distribution is on the coast of the tropical region, then extends to 30° towards the north and south latitudes (Twilley 2019; Giri 2021). However, mangroves significantly contributed to carbon sequestration (Kauffman et al. 2020; Adame et al. 2021). The ability of mangroves to store carbon above- and belowground should involve a conservation strategy to avoid massive releases of carbon stock by land conversion (Sidik et al. 2018; Crusius 2020; Arifanti et al. 2022; Murdiyarso and Ambo-Rappe 2022) and also to prevent the change in a hydrogeomorphic setting which highly related to the carbon stock dynamic (Sasmito et al. 2020b). In the Sunda Shelf (including Indonesia), agriculture and aquaculture conversion is a major threat contributing about 73% of carbon emissions by mangrove conversion (Adame et al. 2021). Then, mangrove protection is critical to optimizing mangroves' ability to store carbon and as a greenhouse gas (GHG) emissions mitigation (Sasmito et al. 2020b; Arifanti et al. 2022).

In Bali, some mangrove areas are protected by national law such as Ngurah Rai Forest Park and Bali Barat National Park. In comparison, local wisdom protects some areas, such as Nusa Lembongan. Ngurah Rai Forest Park has the largest mangrove area in Bali, which covers about 1,132.00 ha of mangrove forest. Nearly half of this mangrove forest area results from reclamation efforts from former fishponds from 1992-1999 (JICA 1999; Murdiyarso and Ambo-Rappe 2022). Several studies concerning its community structure have been carried out within Ngurah Rai Forest Park, revealing the dominance of *Bruguiera*, *Rhizophora*, and *Sonneratia* (Wiyanto and Faiqoh 2015; Andiani et al. 2021; Sugiana et al. 2021; Sugiana et al. 2022).

Nusa Lembongan is one of the small islands southeast of the mainland. Among other islands, Nusa Lembongan has quite a dense mangrove area, around 202 ha, which resides at the northeastern of the island. Palguna et al. (2017) identified 13 mangrove species belonging to 3 dominant genera: *Rhizophora*, *Ceriops*, and *Xylocarpus*. Previous research findings reveal differing degrees of dominance of mangrove species between these two locations, underscoring the value of conducting studies to compare their species compositions. Such investigations hold significant promise for advancing our understanding of mangrove ecology and the mechanisms behind their vegetation adaptations.

Ngurah Rai Forest Park and Nusa Lembongan have different habitats of mangroves based on the size of the island. Therefore, to study the mangrove responses based on the size of an island, the mangrove composition is important to investigate and compare between the large and the small islands. The small island poses a higher risk of ecosystem damage than the larger one (Veitayaki et al. 2017; Pasaribu et al. 2020; Opa et al. 2021). The species composition on each island should be recorded due to the mangrove adaptability and colonization that creates spatiotemporal variation in species composition (Eddy et al. 2019; Chen et al. 2021). This research aimed to study the floristic composition of the mangrove species in Ngurah Rai Forest Park and Nusa Lembongan through the diversity and community structure assessment.

MATERIALS AND METHODS

Study area

The research was conducted in Ngurah Rai Forest Park and Nusa Lembongan from August 2022 to January 2023, with plot distribution as shown in Figure 1. Ngurah Rai Forest Park is in two administrative regions, Denpasar City and Badung Region, and has the highest mangrove coverage in Bali with 1,132 ha of mangrove. Nusa Lembongan, located in the Klungkung Region, has 202 ha of mangrove coverage. The mangrove forest in Ngurah Rai Forest Park displays substrate characteristics ranging from sandy clay to sand (Prinasti et al. 2020), with a water salinity gradient extending from the upstream to downstream areas (Sugiana et al. 2021). This forest is intersected by six rivers: Rangda, Badung, Mati, Loloan, Sama, and Buaji (Suteja and Purwiyanto 2018). Conversely, the mangrove habitat on Nusa Lembongan represents a natural ecosystem that lacks rivers due to the island's topography. The substrate characteristics here span from clay to sand, with an overall influence of water salinity closely resembling seawater, measuring between 32.5 and 35 ppt (Palguna et al. 2017).

Mangrove species diversity

Mangrove species diversity was assessed using explorative methods in Ngurah Rai Forest Park and Nusa Lembongan. The explorative area uses two main approaches: (i) by exploration from the landward to the middle area or seaward and (ii) by exploration from the seaward using kano.

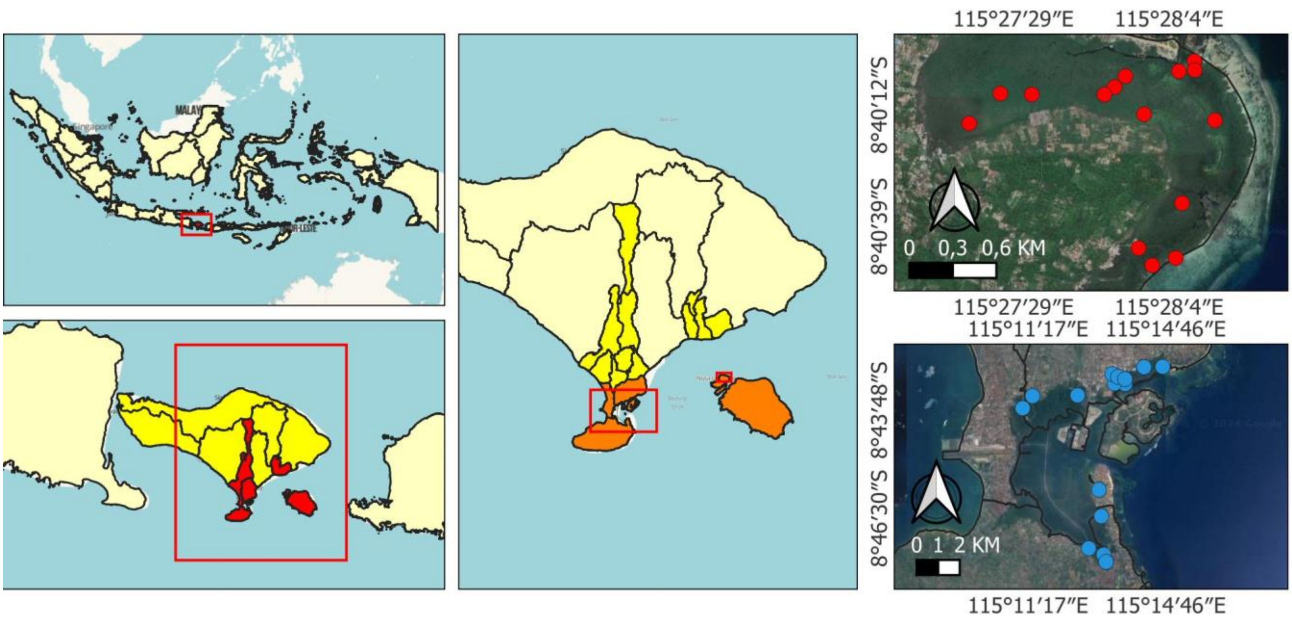

Figure 1. Study site for mangrove community research in Bali, Indonesia. The bottom right is an area of Ngurah Rai Forest Park (Tahura), with the blue showing the plot distribution that is used in Ngurah Rai Forest Park. The top right is area of Nusa Lembongan with the red showing plot distribution used in Nusa Lembongan

Table 1. Criteria for mangrove assessment from the Decree of the Minister of Environment number 201 of 2004 regarding Standard Criteria and Guidelines for Determining Mangrove Damage

Criteria		Coverage (%)	Density (tree ha^{-1})
Good	Dense	>75%	>1,500
	Moderate	50-75%	1,000-1,500
Poor	Sparse	<50 %	<1,000

The names of the species were recorded and listed. The accepted name for each species refers to the digital database by Kew Botanical Garden through https://powo.science.kew.org/ (POWO 2023), while the vernacular name refers to the Noor et al. (1999).

Mangrove community structure measurement

The mangrove community data were collected using the plot method. Next, 15 quadratic 10 × 10 m plots were distributed randomly in each area (Ngurah Rai Forest Park and Nusa Lembongan, n = 30), as shown in Figure 1. Mangrove density, frequency, and dominancy for each species and growth forms were determined by measuring the Diameter at Breast Height (DBH) value. Based on DBH value, mangrove stands were separated into three growth forms: tree (DBH > 10 cm), sapling (DBH 2–10 cm), and seedling (DBH < 2 cm). The number of individuals for each species and growth form was used to calculate Density (D) and Relative Density (DR), the appearance of species in plots was used to calculate Frequency (F) and Relative Frequency (FR), the basal area of each species used to calculate Dominancy (Do) and Relative Dominancy (DoR), and then the sum of the relative values used to calculate Important Value Index (IVI). Mangrove species identification was used in three main identification books from Kitamura et al. (1997), Noor et al. (1999), and Tomlinson (2016). The mangrove canopy cover was taken using modified hemispherical photography from Jennings et al. (1999) and Ishida (2004) by digital analysis using photo and image processing in the ImageJ program. In addition, 9 photos were taken for every quadratic plot (n=135 for each mangrove area).

Data analysis

The community index that was used in the mangrove analysis was the Shannon-Wiener Index of Diversity (H'), Index of Dominance (C), and Index of Evenness (E). Mangrove healthiness was also calculated based on the Decree of the Minister of Environment number 201 of 2004 regarding the Standard Criteria and Guidelines for Determining Mangrove Damage (Table 1).

RESULTS AND DISCUSSION

Diversity of mangrove species in Ngurah Rai Forest Park and Nusa Lembongan

The species diversity of mangroves in Ngurah Rai Forest and Nusa Lembongan comprises 20 true mangrove species classified in 11 genera and 8 families, as shown in Table 2. Among those species, 18 were found in Ngurah Rai Forest Park, and 15 in Nusa Lembongan, and some species have limited distribution. The species that were only distributed in Ngurah Rai Forest Park were *Avicennia alba, Sonneratia caseolaris, Xylocarpus moluccensis, Xylocarpus rumphii*, and *Aegiceras corniculatum*. In contrast, the only distributed species in Nusa Lembongan were *Rhizophora × lamarckii* and *Scyphiphora hydrophylacea*. Those two species that are only in Nusa Lembongan are also the species that were recently listed (new record for species distribution).

Mangrove community structure of Ngurah Rai Forest Park and Nusa Lembongan

The community structure of mangrove species in Ngurah Rai Forest Park, shown in Table 3, is based on the growthforms. The highest tree density was *Sonneratia alba* with 746.67 ind ha^{-1}, followed by *Rhizophora mucronata* (426.67 ind ha^{-1}) and *R. apiculata* (226.67 ind ha^{-1}). The sapling growthform is composed of eight species that are dominated by *R. mucronata* (800.00 ind ha^{-1}), *R. apiculata* (793.33 ind ha^{-1}), and *S. alba* (433.33 ind ha^{-1}). Seedling only had four species with the highest density: *R. mucronata* (800.00 ind ha^{-1}), followed by *B. gymnorhiza* (500.00 ind ha^{-1}), *S. alba* (180.00 ind ha^{-1}), and *R. apiculata* (160.00 ind ha^{-1}).

In Nusa Lembongan, mangrove tree density was dominated by *Rhizophora stylosa* 206.67 ind ha^{-1}, followed by *B. gymnorhiza* (160.00 ind ha^{-1}) and *S. alba* (140.00 ind ha^{-1}). The highest density for saplings was R. stylosa with 1426.67 ind ha-1, followed by *Xylocarpus granatum* (500.00 ind ha^{-1}) and *R. apiculata* (466.67 ind ha^{-1}). Then for seedling, the species with the highest density was *R. stylosa* with 266,67 ind ha^{-1}, followed by *B. gymnorhiza* (153.33 ind ha^{-1}).

The tree growthform with the highest IVI in Ngurah Rai Forest Park is *S. alba*, with 160.91%. Of this value, the proportion of DR is 49.78%, FR is 40.00%, and DoR is 71.13%. The high value of DoR compared to DR and FR indicates that stand size has a more dominant role. This contrasts with *R. mucronata*, which has an IVI of 65.09% with a proportion of DR 28.44%, FR 20.00%, and DoR 16.65%. In *R. mucronata*, DR has a higher contribution than FR and DoR. The same pattern is also observed in tree growthform in Nusa Lembongan. *Rhizophora stylosa* has the highest IVI of 90.04%, with DR's main contribution at 32.29% (FR 26.92%, DoR 30.83%). The species with the second highest IVI is *S. alba*, with a value of 75.91%, with the main contribution of DoR at 30.96% (DR 21.88%, FR 23.08%).

For growthform sapling, the highest IVI in Ngurah Rai Forest Park is *R. apiculata* with 90.39% (DR 32.43%, FR 21.43%, DoR 36.54%), followed by *R. mucronata* with 89.70% (DR 32.70%, FR 21.43%, DoR 35.58%) and *S. alba* with 64.35% (DR 17.71%, FR 32.14%, DoR 14.49%). In Nusa Lembongan, the highest IVI in sapling is *R. stylosa* with 122.62% (DR 43.32%, FR 31.58%, DoR 47.72%), while other species have IVI <50%, such as *R. apiculata* with 47.26% (DR 14.17%, FR 15.79%, DoR 17.31%).

Table 2. Species composition of mangrove in Ngurah Rai Forest Park and Nusa Lembongan, Bali, Indonesia

Family	Species	Vernacular name	Distribution	
			Ngurah Rai Forest Park	Nusa Lembongan
Acanthaceae	*Avicennia alba* Blume	Api-api, mangi-mangi putih, boak	+	-
Acanthaceae	*Avicennia marina* (Forssk.) Vierh.	Api-api putih, sia-sia putih, pejapi, nyapi	+	+
	Avicennia marina var. *rumphiana* (Hallier f.) Bakh	Api-api, sia-sia	+	+
Acanthaceae	*Avicennia officinalis* L.	Api-api, api-api ludat, sia-sia putih, papi	+	+
Combretaceae	*Lumnitzera racemosa* Willd.	Api-api balah, susup, kedukduk, api-api jambu	+	+
Euphorbiaceae	*Excoecaria agallocha* L.	Buta-buta, kayu wuta, babutah	+	+
Lythraceae	*Pemphis acidula* J.R.Forst. & G.Forst.	Sentigi, mentigi	+	+
Lythraceae	*Sonneratia alba* Sm.	Prapat, pidada, bogem, posi-posi	+	+
Lythraceae	*Sonneratia caseolaris* (L.) Engl.	Pidada, pedada, perepat, bogem	+	-
Meliaceae	*Xylocarpus granatum* J.Koenig	Nyiri, niri, nyiri hutan	+	+
Meliaceae	*Xylocarpus moluccensis* (Lam.) M.Roem.	Nyiri batu, nyuru, parasar	+	-
Meliaceae	*Xylocarpus rumphii* (Kostel.) Mabb.	Nyirih, banang-banang	+	-
Primulaceae	*Aegiceras corniculatum* (L.) Blanco	Teruntun, perpat kecil, tudung laut	+	-
Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lam. ex Savigny	Tanjang, putut, lindur, pertut, taheup	+	+
Rhizophoraceae	*Ceriops decandra* (Griff.) W.Theob.	Tingi, tengal, luru, bido-bido	+	+
Rhizophoraceae	*Ceriops tagal* (Perr.) C.B.Rob.	Tingi, tengal, lonro, bido-bido, mangi-mangi darat	+	+
Rhizophoraceae	*Rhizophora apiculata* Blume	Bakau putih, mangi-mangi, nakau akik	+	+
Rhizophoraceae	*Rhizophora mucronata* Poir.	Bakau hitam, bakau merah, bangka itam	+	+
Rhizophoraceae	*Rhizophora x lamarckii* Montrouz.	-	-	+
Rhizophoraceae	*Rhizophora stylosa* Griff.	Bakau kurap, bangko, slindur	+	+
Rubiaceae	*Scyphiphora hydrophylacea* C.F.Gaertn.	Prepat lanang, cingam, duduk rayap	-	+

Annotations: (+) present; (-) absent

In growthform seedlings, the highest IVI in Ngurah Rai Forest Park is *R. mucronata* with 76.56% (DR 48.78%, FR 27.78%), followed by *S. alba* at 49.86% (DR 10.93%, FR 38.89%) and *B. gymnorhiza* at 47.15% (DR 30.49%, FR 16.67%). In Nusa Lembongan, the species with the highest IVI is *R. stylosa* with 93.65% (DR 48.19%, FR 45.45%), followed by *B. gymnorhiza* at 45.89% (DR 27.71%, FR 18.18%).

Mangrove community status of Ngurah Rai Forest Park and Nusa Lembongan

Mangrove community status in Ngurah Rai Forest Park and Nusa Lembongan is based on four parameters. Three parameters were continuance from vegetation analysis: the Index of Diversity, Index of Dominance, and Index of Evenness shown in Figure 3. The fourth parameter was based on the Minister of Environment Decree of the Minister of Environment number 201 of 2004 regarding Standard Criteria and Guidelines for Determining Mangrove Damage shown in Table 5.

Based on Figure 3, Nusa Lembongan had a higher Index of Diversity (H') than Ngurah Rai Forest Park in all growthforms. H' value for growthform tree was 1.27 in Ngurah Rai Forest Park, compared with 1.64 in Nusa Lembongan. For saplings, the H' value in Ngurah Rai Forest Park was 1.62, while in Nusa Lembongan was slightly higher at 1.76. For seedlings, the H' value in Ngurah Rai Forest Park was 1.32, while in Nusa Lembongan was 1.47. All the H' values in the range of 1-3 indicate that all the growth in both locations is categorized as Moderate species diversity.

The Index of Dominance (C) value in both locations is < 0.5, implying a stable community without major domination of certain species. The C value for trees in Ngurah Rai Forest Park was 0.36 which is higher than Nusa Lembongan with 0.23. This is due to the condition of the mangrove community in Ngurah Rai Forest Park, which several major mangrove species, such as *S. alba, R. apiculata*, and *R. mucronata*, have zoned. This also causes the number of mangrove species found in vegetation plots in Ngurah Rai Forest Park (8 species) to be less than Nusa Lembongan (9 species). However, exploratively, the number of species in Ngurah Rai Forest Park is more than in Nusa Lembongan, as shown in Table 2.

The Index of Evenness (E) indicates how evenly the distribution of individual species in the community is. For the E value, the closer to the value 1 (or > 0.5) represents a more even species distribution, and vice versa if the value is closer to 0. Based on that criterion, all the growthforms in Ngurah Rai Forest Park and Nusa Lembongan show an even distribution of the species, as shown in Figure 3c. Trees and saplings were more evenly distributed in Nusa Lembongan than in Ngurah Rai Forest Park. The E value for trees and saplings in Nusa Lembongan was 0.79 and 0.80, while in Ngurah Rai Forest Park was slightly lower with 0.71 for trees and 0.78 for saplings. In contrast, seedlings show a higher E value in Ngurah Rai Forest Park (0.95) than in Nusa Lembongan (0.82).

Table 3. Mangrove community structure in Ngurah Rai Forest Park, Bali, Indonesia

Species	Density (ind ha^{-1})	DR (%)	FR (%)	DoR (%)	IVI (%)
Tree					
Avicennia marina	6.67	0.44	4.00	0.14	4.59
Bruguiera gymnorhiza	66.67	4.44	12.00	4.20	20.64
Lumnitzera racemosa	26.67	1.78	4.00	0.83	6.61
Rhizophora apiculata	226.67	15.11	20.00	7.05	42.16
Rhizophora mucronata	426.67	28.44	20.00	16.65	65.09
Sonneratia alba	746.67	49.78	40.00	71.13	160.91
Total	1500.00	100.00	100.00	100.00	300.00
Sapling					
Avicennia marina	80.00	3.27	3.57	2.15	9.00
Bruguiera gymnorhiza	233.33	9.54	10.71	7.07	27.32
Lumnitzera racemosa	13.33	0.54	3.57	0.46	4.58
Rhizophora apiculata	793.33	32.43	21.43	36.54	90.39
Rhizophora mucronata	800.00	32.70	21.43	35.58	89.70
Rhizophora stylosa	86.67	3.54	3.57	3.66	10.78
Sonneratia alba	433.33	17.71	32.14	14.49	64.35
Xylocarpus granatum	6.67	0.27	3.57	0.04	3.88
Total	2446.67	100.00	100.00	100.00	300.00
Seedling					
Bruguiera gymnorhiza	500.00	30.49	16.67		47.15
Rhizophora apiculata	160.00	9.76	16.67		26.42
Rhizophora mucronata	800.00	48.78	27.78		76.56
Sonneratia alba	180.00	10.98	38.89		49.86
Total	1640.00	100.00	100.00		200.00

Table 4. Mangrove community structure in Nusa Lembongan, Bali, Indonesia

Species	Density (ind ha^{-1})	DR (%)	FR (%)	DoR (%)	IVI (%)
Tree					
Avicennia marina var. *rumphiana*	6.67	1.04	3.85	0.51	5.40
Bruguiera gymnorhiza	160.00	25.00	15.38	25.97	66.36
Ceriops tagal	6.67	1.04	3.85	0.48	5.37
Rhizophora apiculata	93.33	14.58	19.23	8.85	42.66
Rhizophora stylosa	206.67	32.29	26.92	30.83	90.04
Rhizophora x lamarckii	20.00	3.13	3.85	1.95	8.92
Sonneratia alba	140.00	21.88	23.08	30.96	75.91
Xylocarpus granatum	6.67	1.04	3.85	0.45	5.34
Total	640.00	100.00	100.00	100.00	300.00
Sapling					
Avicennia marina	340.00	10.32	2.63	5.53	18.49
Avicennia marina var. *rumphiana*	20.00	0.61	2.63	0.49	3.73
Bruguiera gymnorhiza	273.33	8.30	13.16	9.66	31.12
Ceriops tagal	200.00	6.07	10.53	5.19	21.79
Rhizophora apiculata	466.67	14.17	15.79	17.31	47.26
Rhizophora stylosa	1426.67	43.32	31.58	47.72	122.62
Rhizophora x lamarckii	6.67	0.20	2.63	0.05	2.88
Sonneratia alba	60.00	1.82	10.53	2.83	15.18
Xylocarpus granatum	500.00	15.18	10.53	11.22	36.93
Total	3293.33	100.00	100.00	100.00	300.00
Seedling					
Avicennia marina	40.00	7.23	9.09	-	16.32
Bruguiera gymnorhiza	153.33	27.71	18.18	-	45.89
Ceriops tagal	46.67	8.43	9.09	-	17.52
Rhizophora apiculata	20.00	3.61	9.09	-	12.71
Rhizophora stylosa	266.67	48.19	45.45	-	93.65
Xylocarpus granatum	26.67	4.82	9.09	-	13.91
Total	553.33	100.00	100.00	-	200.00

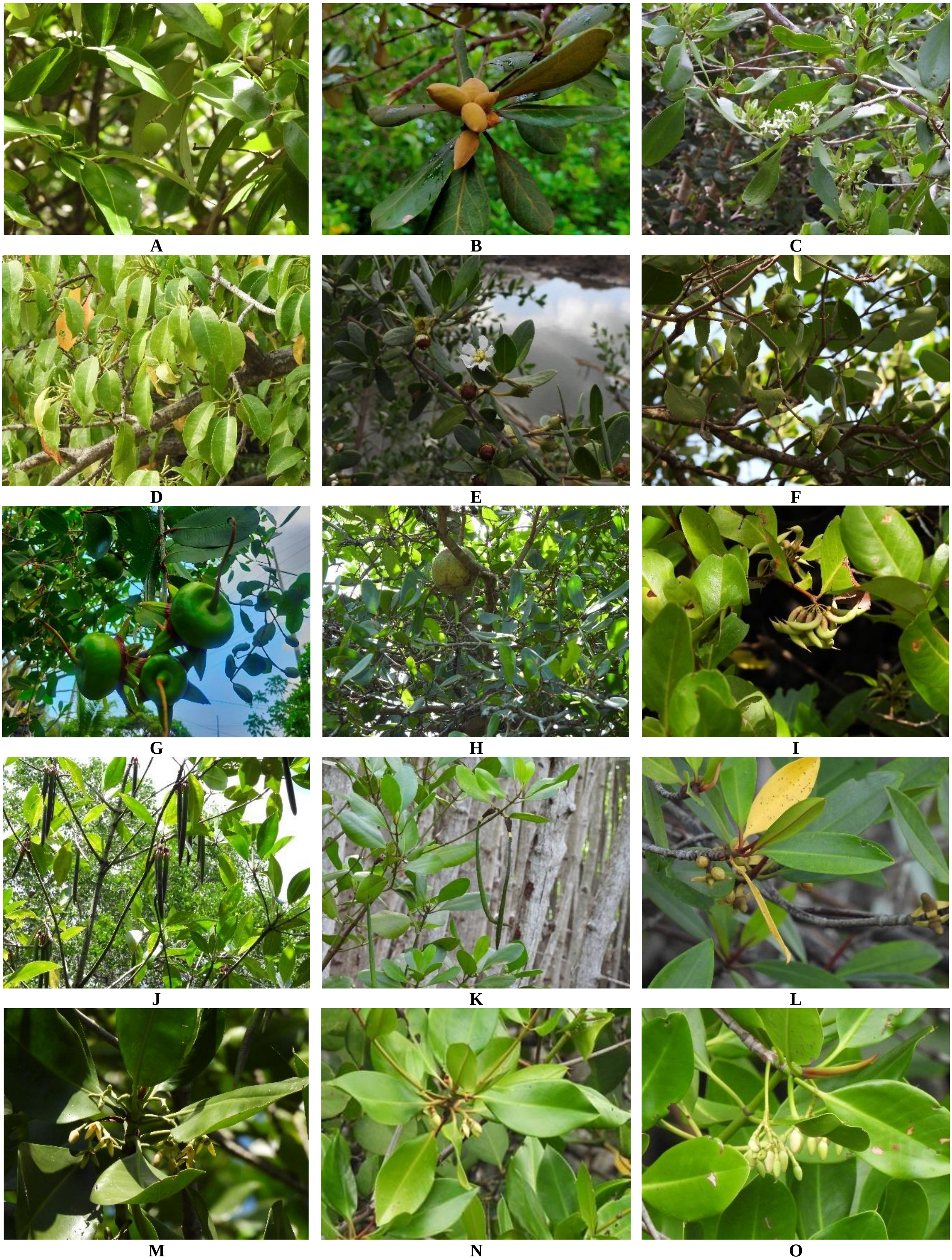

Figure 2. Mangrove species in Ngurah Rai Forest Park and Nusa Lembongan, Bali, Indonesia. A. *Avicennia marina*; B. *Avicennia marina* var. *rumphiana*; C. *Lumnitzera racemosa*; D. *Excoecaria agallocha*; E. *Pemphis acidula*; F. *Sonneratia alba*; G. *Sonneratia caseolaris*; H. *Xylocarpus granatum*; I. *Aegiceras corniculatum*; J. *Bruguiera gymnorhiza*; K. *Ceriops tagal*; L. *Rhizophora apiculata*; M. *Rhizophora mucronata*; N. *Rhizophora* × *lamarckii*; O. *Rhizophora stylosa*

Table 5. The mangrove community status in Ngurah Rai Forest Park and Nusa Lembongan, Bali, Indonesia based on the Decree of the Minister of Environment number 201 of 2004 regarding Standard Criteria and Guidelines for Determining Mangrove Damage

Location	Parameters		Category
	Coverage (%)	Density (tree ha^{-1})	
Ngurah Rai Forest Park	66.36 ± 16.41	3,267 ± 1,370	Good with dense trees
Nusa Lembongan	59.79 ± 13.32	2,507 ± 1,125	Good with dense trees

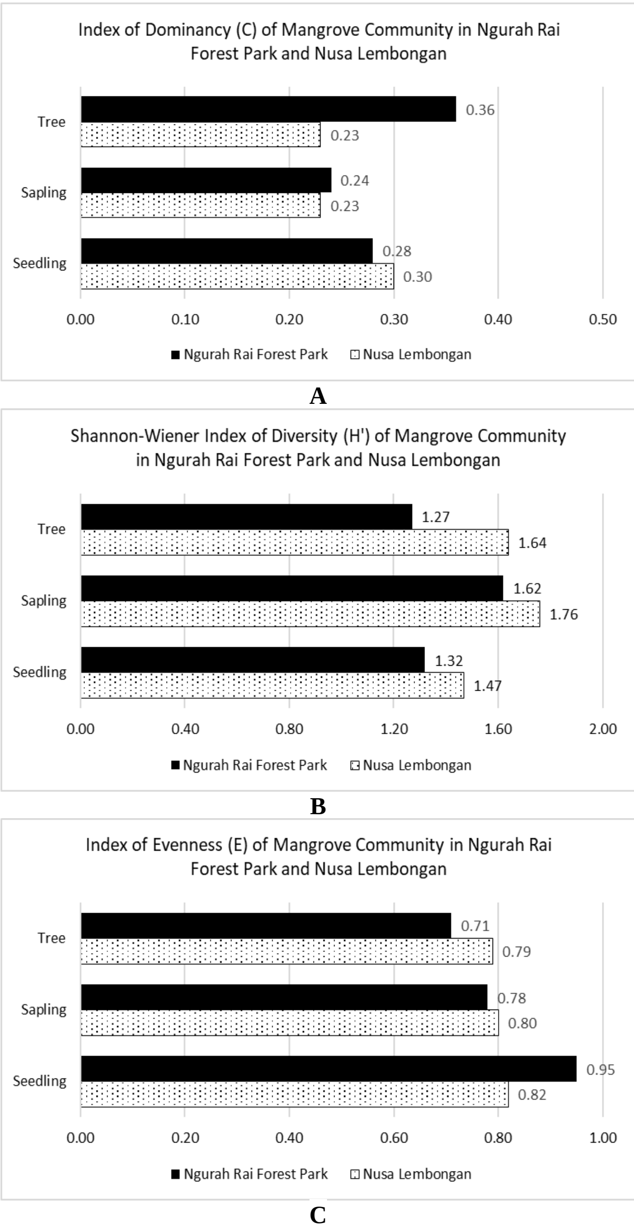

Figure 3. The mangrove community status in Ngurah Rai Forest Park and Nusa Lembongan, Bali, Indonesia. A. Shannon-Wiener Index of Diversity; B. Index of Dominance; and C. Index of Evenness

Discussion

Ngurah Rai Forest Park has more species than Nusa Lembongan. Based on the potential mangrove area, Ngurah Rai Forest Park provides more area (1,132 ha) than Nusa Lembongan (202 ha). The more spacious area will provide more habitat variations for mangroves (Pasaribu et al. 2020). In addition, some areas in Ngurah Rai Forest Park were abandoned shrimp fisheries that might have submerged the nutrients in the sediment (Wijaya et al. 2023). The sediment nutrient plays an important role in mangrove colonization.

This study also recorded a variety of *Avicennia marina*, which is *Avicennia marina* var. *rumphiana*. This variety shared the same traits as *A. marina* in habitus, stem, leaf shape, flower, and fruit. The major traits that differentiate this variety are the trichome density. *Avicennia marina* var. *rumphiana* have dense trichomes and are browner on the abaxial leaf, while *A. marina* has pale green abaxial leaves.

Among the listed species, the family of Rhizophoraceae has the highest species composition. Rhizophoraceae comprises seven species, four belonging to the *Rhizophora*, such as *R. apiculata*, *R. mucronata*, *R. × lamarckii*, and *R. stylosa*. Some morphological traits that can distinguish these species are the number of flowers, propagule size, and leaf size. Based on the number of flowers, *R. apiculata* has 2 flowers for each inflorescent, while *R. × lamarckii* has 3 to 4 flowers, *R. mucronata* has 4 to 8 flowers, and *R. stylosa* has 8 to 16 flowers. Distinguishing *Rhizophora* species by leaf character is relatively difficult to do when not compared to each other. In general, all genera of *Rhizophora* have an oval-shaped leaf. The order of species with the smallest to largest leaf size is *R. apiculata, R. × lamarckii*, *R. stylosa,* and *R. mucronata.*

For propagule size, *R. apiculata* has the smallest propagule (18–25 cm), slightly different from *R. stylosa* (20–30 cm), while the largest is *R. mucronata* (40–70 cm). *Rhizophora × lamarckii* is a natural hybrid of *R. apiculata* and *R. stylosa,* but unable to produce fruit (Tomlinson 2016). The incapability to produce fruit is an important diagnostic characteristic to differentiate *R. × lamarckii* from its parent since this species shares intermediate characteristics in vegetative traits with its parent. In advance, the chemical constituents of *R. × lamarckii* also show combinations between its parents (Chan and Wong 2009).

According to the community structure data, the density of trees in Ngurah Rai Forest Park (1500.00 ind ha^{-1}) is greater than in Nusa Lembongan (640.00 ind ha^{-1}), but from the species composition, Ngurah Rai Forest Park has six species of trees compared with Nusa Lembongan that has eight species of trees. This indicates the dominance of major mangrove species that form specific stands or zones, so the migration of other species is very low, especially in the *Rhizophora* zone.

The classification of growthform based on trunk diameter is slightly detrimental to mangrove species on small islands such as Nusa Lembongan. On small islands, the size of mangroves tends to be shorter (dwarf) with a smaller diameter, so they tend to be in the sapling range with a diameter of 2–10 cm. This is also supported by the sapling density in Nusa Lembongan with 3293.33 ind ha^{-1}, which is higher than Ngurah Rai Forest Park with 2446.67 ind ha^{-1}. In addition, the branching pattern of mangroves on small islands tends to be denser (Dharmawan and Pramudji 2020), especially in areas dominated by *Rhizophora.* As a result, light penetration is reduced, and propagule transport is inhibited (Setyadi et al. 2021). This causes the low density of seedlings in Nusa Lembongan. These results follow some research that stated that small island mangroves in Indonesia tend to have smaller diameter sizes but higher density (Dharmawan and Pramudji 2020).

Trees and saplings are the major components that construct the ecosystem characteristics. *Rhizophora, Sonneratia,* and *Bruguiera* are the main genera in Ngurah Rai Forest Park and Nusa Lembongan, which compose the mangrove community. As reported by Sugiana et al. (2022), *Rhizophora* and *Sonneratia* cumulatively composed more than 90% area of Ngurah Rai Forest Park. On the tree growth for growth form, *S. alba* has a wide canopy and extensive root branching with pneumatophores appearing on the surface of the substrate. The large trunk diameter indicated by the high value in DoR supported the wide canopy. These characteristics make it difficult for other species to grow around *S. alba,* so *Sonneratia*-dominated areas tend to have low species diversity (Sugiana et al. 2022; Wijaya et al. 2023). In addition, species in the genus *Sonneratia* tend to be light-demanding species, making it more difficult for other species to coexist due to light competition (Zhu et al. 2022). *Sonneratia* also can produce allelochemicals that inhibit other species' growth and development (Hasegawa et al. 2014; Sasamoto et al. 2018).

For saplings, the existence of *S. alba* was more influenced by the FR rather than DR and DoR. This is in contrast with the tree growthform that DoR dominated. As the sapling is developing from seedling, this pattern is highly related to the seed dispersal of *S. alba,* which produces floating fruit that can reach a wider area and carry many seeds. On the contrary, with *S. alba*, the *Rhizophora* species tend to be clumped and form an exclusive zone with a high density of stands. Growthform trees in *Rhizophora* tend to experience competition on the growing space or substrate. The larger the tree, the more massive the root reaches a wider range, causing intra- and inter-species competition in the *Rhizophora* genus. Another species that can form dense stands is *B. gymnorhiza*. The pattern of substrate competition may be similar to *Rhizophora* since the knee roots in *B. gymnorhiza* have a wide coverage. However, these knee roots tend to appear when the stand is already big enough. *B. gymnorhiza* tends to exhibit small prop roots near the main trunk to support the stand when in juvenile. In addition, the *Bruguiera* crown pattern tends to be straight with a small trunk circumference, providing many places for other individuals in the same plot. Compared to *Rhizophora* with the same height, the trunk of *B. gymnorhiza* will look very slender.

Several factors cause the high density of *Rhizophora*, but two of the main factors are salinity tolerance and vivipary seed. Species in the genus *Rhizophora* have a wide distribution in various salinity. *Rhizophora stylosa* in Nusa Lembongan can be found from the middle zone (in some areas, it even occurs in the landward zone) to the seaward zone. Meanwhile, some species tend to show some limitations in distribution, such as *R. apiculata,* which prefers near the seaward zone, and *R. mucronata* prefers the landward zone (Setyadi et al. 2021). As for vivipary seeds, all species in the family of Rhizophoraceae (*Rhizophora*, *Bruguiera*, *Ceriops*, and *Kandelia*) produce vivipary seeds that can increase the colonization rate in the mangrove area (Twilley 2019; Fickert 2020). Vivipary refers to the embryo in the seeds that have already germinated and breaks the fruit wall while the fruit is still attached to the parent plant (Tomlinson 2016; Twilley 2019).

This viviparous characteristic causes the species composition of growthfrom seedlings to be dominated by species from the Rhizophoraceae family. Three of the four seedling species in Ngurah Rai Forest Park and four of the six seedling species in Nusa Lembongan are species of the Rhizophoraceae family. *Rhizophora mucronata* had the highest IVI score in Ngurah Rai Forest Park, while *R. stylosa* had the highest value in Nusa Lembongan for seedlings. This is closely related to plant regeneration. These two species also have high value in tree and sapling growthforms, so they can produce lots of propagules to colonize new areas. In addition, propagules from *Rhizophora* tend to have high shade tolerance so that they can survive in the canopy layering of mangroves with high canopy density. According to the results, the lowest density of *R. apiculata* towards *R. mucronata* (Ngurah Rai Forest Park) and *R. stylosa* (Nusa Lembongan) caused by the zonation by those *Rhizophora* species. Athough distributed in various locations, the zonation of *R. apiculata* was tighter than those two.

In community indexes, the H' value in the mangrove community rarely exceeded 3, indicating a high species diversity. Because of the limited number of true mangrove species and the tendency of mangrove major to form a zonation, the H' value will be 1–3. In the natural area with mature zonation of mangrove major, the H' is even slightly below 1 (Wijaya et al. 2023). This can be attributed to utilizing the H' index, which is sensitive to changes in species dominance within a community. If one or several species dominate the community, this index can be skewed towards those dominant species and might not accurately reflect the overall diversity.

The Index of Dominance and Index of Evenness is very dependent on the condition of the sample, so it cannot be used as the main reference. With the characteristics of major and minor mangroves, it is likely that minor mangroves are not included in the plot, so they are not included in the calculation. In this case, some minor mangrove species found during exploration but not in the sampling plot are *Avicennia alba*, *Avicennia officinalis*, *Excoecaria agallocha, Pemphis acidula, Sonneratia caseolaris, Xylocarpus moluccensis, Xylocarpus rumphii, Aegiceras corniculatum, Ceriops decandra,* and *Scyphiphora hydrophylacea*. However, the value obtained can be used to screen the condition of mangrove communities in general.

Therefore, to provide additional information about the condition of mangrove communities, an analysis was carried out based on guidelines from the Decree of the Minister of Environment number 201 of 2004 regarding Standard Criteria and Guidelines for Determining Mangrove Damage. Based on the results in Table 5, the condition of mangrove communities in Ngurah Rai Forest Park and Nusa Lembongan is Good with Dense Trees. The canopy coverage value in Ngurah Rai Forest Park is higher than Nusa Lembongan, which is 66.36 ± 16.41% compared to 59.79 ± 13.32%. The high tree density influences high canopy cover stands in Ngurah Rai Forest Park, which is 3,267 ± 1,370 tree ha^{-1}; in Nusa Lembongan, it is 2,507 ± 1,125 tree ha^{-1}. The high density of trees in Ngurah Rai Forest Park shows the success of mangrove rehabilitation that has been carried out since 1992 after the conversion of fisheries ponds (Murdiyarso and Ambo-Rappe 2022).

Many factors influence the condition of the mangrove community; one of the major factors is the raised global temperature, which changes the precipitation and causes alterations in salinity gradient and sedimentation (Veitayaki et al. 2017; Cravo et al. 2021). Next, sedimentation is closely related to nutrient content in mangrove ecosystems, especially in the middle and landward zones, dominated by allochthonous sediment (Sasmito et al. 2020a; Murdiyarso et al. 2021). Along with salinity, sediment or nutrients were the main drivers constructing the species composition in the mangrove community (Setyadi et al. 2021). Those alterations will influence the mangrove community structure on large islands, and the impact will emphasized in small islands (Veitayaki et al. 2017; Dharmawan and Pramudji 2020).

As a climate change mitigation, the damaged mangroves by natural disasters and anthropogenic activities have been massively restored. The government of Indonesia has targeted to restore more than 600,000 ha of damaged mangrove forest by the end of 2024, according the Presidential Regulation Number 120 of 2020 (Nurhati and Murdiyarso 2022). Although many restorations are carried out to restore the condition of mangroves, they must be done carefully and consider some aspects of the mangrove ecosystem, such as the hydrology, landscape, and mangrove species (Lee et al. 2019; Qu et al. 2019). Among many mangrove species, most of the mangrove restoration projects planted one dominant species, *Rhizophora* (Murdiyarso and Ambo-Rappe 2022; Sugiana et al. 2022). Some mangrove species can be invasive, causing changes in the composition of native mangrove communities. In addition, human-mediated dispersal through mangrove restoration without the preliminary study of the limitation of species dispersal can also disturb the mangrove biogeography (Chen et al. 2021).

In conclusion, Ngurah Rai Forest Park has 18 true mangrove species compared with 15 species in Nusa Lembongan. The family of Rhizophoraceae has the most species composition, with 7 species. The mangrove community structure is composed of *S. alba* and *Rhizophora* (*R. apiculata, R. mucronata,* and *R. stylosa*) in trees, saplings, and seedlings. *Sonneratia alba* has more impact in relative dominancy (DoR), while the *Rhizophora* has more impact in relative density (DR). The mangrove community status based on the Shannon-Wiener Diversity Index is Moderate in Ngurah Rai Forest Park and Nusa Lembongan in all growth forms (trees, saplings, and seedlings). The present study revealed the mangrove community is in stable condition with even distribution, and also in Good with Dense Trees for the region's sustainable development.

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