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MONITORING OF DIVERSITY, CHARACTERISTICS, THREATENING RATE AND POTENCY OF MANGROVE VEGETATION IN DENPASAR, BALI, INDONESIA

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ABSTRACT

Mangrove forests cover 137,600 km2 of coastline in 118 countries with 38.7% in Asia including Indonesia. The purpose of this study was to analyze the diversity, characteristics, threatening rate, and potency of mangrove plants found in the mangrove forest area of Denpasar City, Bali. Monitoring activities on mangrove vegetation has great importance for the balance of ecosystems and the livelihoods of people living around the mangrove area. Vegetation data were collected using systematic sampling. This method is based on the assumption that the number of individual plants per unit area can be calculated as the average distance between the plants. The data obtained is then analyzed based on the parameters of Characteristics, Frequency, Density, Dominance, Relative Frequency, Relative Density, Relative Dominance, Important Value, and Index Diversity. The results showed that there were 12 plant species that were identified, and 35% of species were categorized as "true mangrove" species. Denpasar's mangrove forests are dominated by *Soneratia alba* with an Important Value Index of 157% and secondly, species is *Rhizophora mucronota* by 52%. The diversity index (H') is 0.65, which shows that the diversity of vegetation in the mangrove area of Denpasar is homogeneous. There are 2 mangrove species that need further monitoring based on IUCN Red list data, namely *Thespesia populnea* and *Ceriops decandra*. Thus, efforts are still needed to protect and restore the mangrove ecosystem, especially for species that have the potential that can be developed as sustainable products and ecotourism areas in the city of Denpasar.

Keywords: *Diversity; Vegetation; Diversity index; Mangrove; Coastal Area*
Running title: Monitoring of mangrove vegetation in Indonesia

Introduction

Indonesia is the largest archipelago country in the world with a total area of 6.32 million kilometres (km^2) (Puspitawati, 2011). Likewise, Indonesia's coastal areas which have a wealth of very rich natural resources such as mangrove forests, coral reefs, sea grasses, and even fisheries (Hutomo *et al*., 2005; Kurniawan *et al*., 2019a). This gives its own advantages for coastal communities to prosper their lives. One of the natural resources that provide many benefits is mangrove forests. Ecologically, mangrove forests function as a component of associations between other ecosystems such as sea grass beds and coral reefs, a strong and sturdy root system that is able to withstand waves and strong winds, withstand mud and protect beaches from erosion and flooding (Al-Sareji *et al*., 2020; Imron, Kurniawan, & Soegianto, 2019; Khaery, 2015; Kurniawan *et al*., 2019b).

Potential that can be obtained from mangrove forests in supporting the community's economy is as estuarine fisheries, ecotourism, mangrove fruit, and leaves that can be used as raw material for medicines in the pharmaceutical field (Imron, Kurniawan, Soegianto, *et al*., 2019; Kathiresan *et al*., 2001; Singh, 2019). The potential of the mangrove can be utilized if the mangrove forest ecosystem can be preserved (Imron *et al*., 2020; Kurniawan *et al*., 2020; Wang *et al*., 2019). The mangrove ecosystem is the main chain that acts as a producer in the coastal ecosystem food web. This ecosystem has high productivity by providing abundant food for various types of marine animals and providing a breeding ground, spawning and raising children for several species of fish, shellfish, crabs, and shrimp (Gnanappazham *et al*., 2011). The mangrove habitat is one of the most productive ecosystems on earth, so their low level of vegetation diversity can cause a decrease in the wealth of natural species that live around mangrove forests (Sousa *et al*., 2011).

Mangrove forests have a dual function and are a very important chain in maintaining the balance of the biological cycle in water (Kadir *et al*., 2020). Walters *et al*. (2008) stated that mangrove forests along the coast and rivers generally provide habitat for various types of fish. Mangrove forests as one of the wetlands in the tropics with easy access and the use of biodiversity components and high land have made these resources as tropical resources whose sustainability will be threatened (Sandilyan *et al*., 2012) and become one of the centers of global environmental issues (Ismail *et al*., 2020; Polidoro *et al*., 2010). The conversion of mangrove forests continues to increase to become agricultural land or fish/shrimp ponds, thus causing a decrease in the productivity of the ecosystem (Satyanarayana *et al*., 2012).

Mangrove ecosystems in the Denpasar City area included in the Taman Hutan Raya (TAHURA) have been determined based on the Decree of the Minister of Forestry (Kepmenhut) Number 544 / Kpts-II / 1993 with an area of approximately 1,373.50 Ha. The NgurahRaiTahura area has six villages in Denpasar City, namely Sanur Kauh, Sidakarya, Sesetan, Serangan, Pedungan, and Pemogan. As well as covering six villages in Badung Regency namely Kuta, Kedongan, Tuban, Jimbaran, Benoa and TanjungBenoa. Management of mangrove areas in Tahura Bali is still not optimal because there are still several major problems including encroachment, pollution, activities of residents around the area that carry out garbage disposal into river bodies and ultimately empties into mangrove areas which are mostly plastic. The aim of this study was to analyze the diversity and characteristics of mangrove plants found in the mangrove forest area of Denpasar City, Bali. This research serves as an effort to maintain the existence of mangrove plants, especially in the Denpasar area and surrounding areas so that the community and the environment are expected to benefit from the existence of this mangrove forest.

Materials and Methods

Sampling Point

This research was conducted at the Mangrove Forest Region I Denpasar City, Bali with coordinates 8°43'30 "LS and 115°11'38" BT. Figure 1 shows the Mangrove forest area of Denpasar, Bali, where the mangrove ecosystem is along the coast.

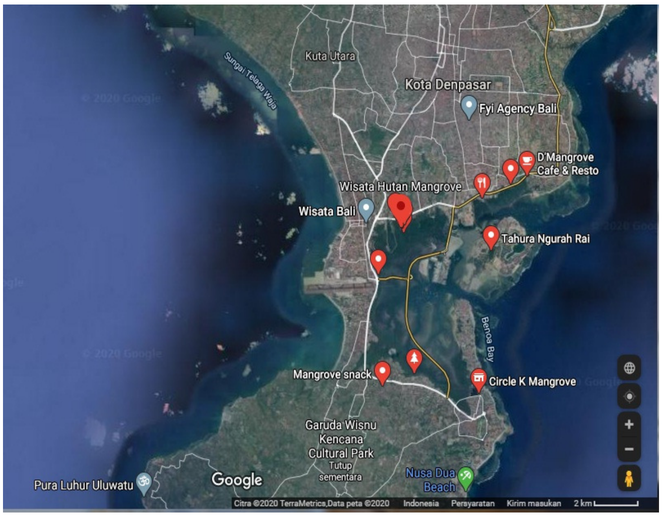

Fig. 1 : Sampling Point (WisataHutan Mangrove) (Google Satellite)

Object of study

The object of this research is the mangrove forest vegetation in the Denpasar City area, Bali. The area under study is a mangrove forest area which is a natural tourism area and is often used by the surrounding community, both directly and indirectly, and is relatively affected by the pollution because it is close to a garbage dump. The method used is a systematic sampling. This method is based on the assumption that the number of individual plants per unit area can be calculated as the average distance between the plants. The method used for vegetation research has different structures from the front and back zones.

Vegetation Data Collection

Data collected during the study are primary and secondary data (Yuliana *et al*., 2019). Primary data are species composition, vegetation structure, and substrate conditions. Secondary data discusses various supporting information obtained from the results of discussions with surrounding communities and literature. The data collection method is carried out by the quadrant transect method which forms a plot measuring 10x10 m^2 for the tree category, 5x5 m^2 for the stake category; and 1x1 m^2 for the seedling category. Each plot measuring 10x10 m^2 was observed to measure the diameter of the tree stem (diameter> 4 cm or perimeter of the stem> 16 cm) using a sewing meter (Irwan *et al*., 2019).Tree level density based on the Decree of the Minister of Environment of the Republic of Indonesia No. 201 of 2001 concerning Standard Criteria and Guidelines for Mangrove Damage Determination.

Data Analysis

Vegetation analysis was carried out by calculating parameters namely (Khaery, 2015):

$$Frequency\ (F) = \frac{number\ of\ plots\ found\ in\ a\ species}{the\ sum\ of\ the\ whole\ plot}$$

$$Density\ (K) = \frac{number\ of\ individuals\ of\ a\ type}{Sampling\ area}$$

$$Dominance\ (D) = \frac{number\ of\ basal\ area\ of\ a\ type}{Sampling\ area} x100\%$$

$$Relative\ Frequency\ (RF) = \frac{frequency\ of\ a\ type}{Frequency\ of\ all\ types} x100\%$$

$$Relative\ Density\ (Dens.R) = \frac{Density\ of\ a\ type}{Total\ density\ of\ all\ types} x100\%$$

$$Relative\ Dominance\ (RD) = \frac{The\ dominance\ of\ a\ type}{Total\ Dominance\ of\ type} x100\%$$

$$Important\ Value\ Index\ (IVI)\ Poles\ and\ Trees = Dens.R + RF + RD$$

$$Important\ Value\ Index\ (IVI)\ Seedlings\ and\ Weaning = Dens.R + RF$$

Diversity (*H'*) is determined based on the Shannon-Wiener index (1949) in (Murrieta-Hernández *et al*., 2014)

$$H' = -\sum_{i}^{s} = 1(Pi)(lnPi)$$

Pi = ni/N

H'= species diversity

ni= number of individuals of a type

N= total number of all types

Results and Discussion

Mangrove floral composition in Denpasar, Bali

The results of observations of the flora composition found in the mangrove forest area of Denpasar at least 12 plant species were recorded inside and outside the sample plot. From the 12 species, 35% are known as true mangrove floral and 30% are known as the Associate Mangrove Flora. The remaining 25% is known as secondary terrestrial vegetation flora and only 10% is included in the swamp vegetation flora (Figure 2).

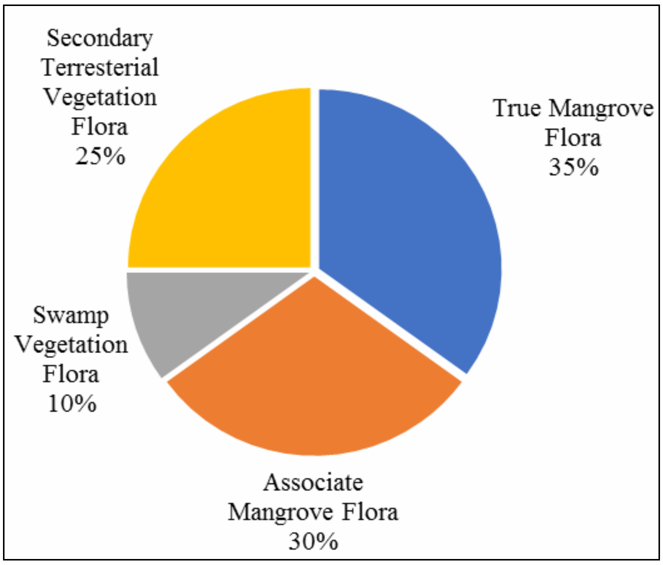

Fig. 2 : The floral composition of mangrove stands in the Mangrove Denpasar, Bali

Furthermore, Table 1 shows the diversity of flora in the mangrove area of Denpasar. Based on data from Table 1, the classification of the flora of mangrove areas is grouped into 4 types namely true mangrove flora, associated mangrove flora, secondary terrestrial vegetation flora, and swamp vegetation flora (Yuliana *et al*., 2019). True mangroves are woody plants, facultative or obligate halophytes that are only found in mangrove areas and are not found on land. According to Tomlinson (2016) states that true mangroves are species which 1) are only found in mangrove forests and not found in terrestrial vegetation communities; 2) has an important role in the structure of mangrove communities and questions the pure standing; 3) specializes in morphology for mangrove environments and 4) has several allocations to neutralize anaerobic sediments by air roots.

The species given the S mark in Table 1 below show flora with secondary vegetation and most species of this flora are pioneering species that invade open forest areas (Yuliana *et al*., 2019). *Lannea coromandalica* is a tree species in the Anacardiaceae family that is widely distributed in South and Southeast Asia including Indonesia. Other species that do not include True mangroves are *Lantana camara, Sesbania grandiflora, Clerodendrum inerme* and *Pandanus* sp.

Table 1: List of vegetation species found in the Denpasar mangrove forest area and their grouping

Scientific name	Local name	M	A	R	S
Soneratia alba	Prapat	X			
Rhizophora mucronata	Bako	X			
Avicennia marina	Api-api	X			
Xylocarpus granatum	Banang-banang	X			
Bruguiera gymnoriza	Tanjang	X			
Thespesia populnea	Kuan	X			
Ceriops decandra	Kenyongnyong	X			
Lannea coromandalica	Kayusantan				X
Lantana camara	Tembelekan		X		
Sesbania grandiflora	Turi		X		
Clerodendrum inerme	Gambirlaut		X		
Pandanus sp.	Pandan			X	

Note: **M**: true mangrove flora; **A**: associate mangrove flora; **R**: swamp vegetation flora; **S**: secondary terrestrial vegetation flora (Yuliana *et al*., 2019)

A further statement from Tomlinson (2016) that all species of the genus Avicennia, Limnitzera, Bruguiera, CeriopsKandelia, Rhizophora and Sonneratia and added to the species *Nypa fructicans* and *Laguncularia racemosa* are considered to be true mangroves and become the main component of mangrove vegetation throughout the world. Mangrove associations will often be found in mangrove environments, but not exclusively because they can also be found outside mangrove habitats (FAO, 2007).

Mangrove vegetation structure in Denpasar area, Bali

There are 7 mangrove species found at the sampling location. Species consisting of mangrove forests *are Soneratia alba, Rhizophora mucronata, Avicennia marina, Xylocarpus granatum, Bruguera gymnoriza, Thespesia populnea,* and *Ceriops decandra*. The results of mangrove vegetation data collection were dominated by mangrove vegetation with the category of trees with the highest density level obtained by *Soneratia alba*, which amounted to 7467 individuals per hectares (ind/ha). The density of trees in that number is based on the standard criteria for mangrove damage according to the Decree of the Minister of the Environment in 2004 it can be concluded that the condition of mangroves in the Denpasar city area is dominated by *Soneratia alba* with the category "Good" with a very dense level of density (> 1,500 ind/ha) (Table 2). The second highest density obtained by *Rhizophora mucronata* that is equal to 1776 (> 1,500 ind/ha). Whereas *Ceriops decandra* has a category with damage because it has a density of less than 1,500 ind/ha.

Soneratia alba is a type of mangrove that grows in rocky habitats and coral sand. *S. alba* that lives in sandy and nearshore habitats has the potential to be exposed to pollutants such as heavy metals. This is supported by the statement ofCordova *et al*. (2017) that *S. alba* samples collected from Pari Island, PulauSeribu show high concentrations of mercury (Hg) in the leaves and are well used as bioindicators of environmental pollution. Thus, the tree level density in the observed plot is expected to be able to absorb heavy metals optimally in the waters surrounding Denpasar mangrove.

Table 2 : Data tabulation of mangrove vegetation.

No	Scientific name	Local name	Tree Level Density (ind/ha)	Level of Damage*
1	*Soneratia alba*	Prapat	7467	Good
2	*Rhizophora mucronata*	Bako	1776	Good
3	*Avicennia marina*	Api-api	603	Heavy damage
4	*Xylocarpus granatum*	Banang-banang	472	Heavy damage
5	*Bruguera gymnoriza*	Tanjang	472	Heavy damage
6	*Thespesia populnea*	Kuan	430	Heavy damage
7	*Ceriops decandra*	Kenyongnyong	272	Heavy damage

*Damage level criteria: number of trees> 1,500 = Good; 1,000-1,500 = moderate damage; <1,000 = heavily damaged (Decree of the Minister of Environment of the Republic of Indonesia No. 201 of 2004)

Mangrove vegetation that grows in the Denpasar mangrove forest area is dominated by Prapat (*Soneratia alba*) which is around 35%, followed by Bako *(Rhizophora mucronata)* 25% and Api-api*(Avicennia marina)* 10% (Table 3). Meanwhile, the lowest dominance was obtained by Kenyongnyong *(Ceriops decandra)* by 5%. According to Yuningsih *et al*. (2014), there are three other important parameters that can be used in monitoring mangrove vegetation, namely relative frequency (RF), relative density (RD), and important value index (IVI). Relative frequency (RF) is the ratio between the frequency of type 1 with the total frequency of all types (Dietriech G. Bengen, 2010). The relative density (RD) according to Bengen (2010) is a comparison of the types of stands to one with the total of all types of stands. Important value (IV) states the magnitude of the influence of a type in influencing ecosystem stability, important value is obtained by adding up the relative frequency, relative density and relative dominance (Sujarwo *et al*., 2011).

Table 3 : Results of Denpasar Mangrove Ecosystem Vegetation Analysis.

Scientific name	Local name	Frequency	Density	Dominance	RF(%)	RD (%)	Dens.R (%)	I.Val (%)	IDI (H') (%)
Soneratia alba	Prapat	0,57	0,0027	0,37	29	35	93	157	0,15
Rhizophora mucronata	Bako	0,43	0,0019	0,0021	22	25	5	52	0,13
Avicennia marina	Api-api	0,27	0,0008	0,0024	14	10	0,6	24,6	0,09
Xylocarpusgranatum	Banang-banang	0,2	0,0007	0,00023	10	9	0,6	19,6	0,08
Bruguiera Gymnoriza	Tanjang	0,17	0,0008	0,00015	9	10	0,4	19,4	0,07
Thespesiapopulnea	Kuan	0,13	0,0003	0,00012	7	4	0,3	11,3	0,06
Ceriopsdecandra	Kenyongnyong	0,17	0,004	0,00005	9	5	0,01	14,01	0,07
Total								297,91	0,65

Notes: RF: Relative Frequency; RD: Relative Dominance; Dens.R: Relative Density; I.Val: Important Value; IDI: Index Diversity

The highest percentage of importance is obtained by *S. alba*, which is 157% (Table 3). The maximum significance value with a percentage of 300% indicates the community of vegetation in a "good place or good habitat". So, when referring to the results of this study, the total percentage of important values (I.Val) obtained in the Denpasar mangrove forest area is 297.91% which means that mangrove forests have a good role in supporting the life of coastal ecosystems.

Referring back to Table 3, it can be seen that the value of the Total Diversity Index in Denpasar mangrove vegetation is equal to 0.65. The Diversity Index in mangrove forests shows that diversity is poor (H<1.0. This is because there are limiting factors such as salinity adjacent to the sea, so that vegetation that is able to survive / adaptation in this area is homogeneous, namely vegetation that has adaptation in the form of air roots. Similar results were also reported by Yuliana *et al.* (2019)that the diversity index of mangrove stands on the banks of the Calik and Banyuasin rivers were respectively 0.82 and 0.78 lower than this study. The higher index of mangrove forest vegetation diversity, the more types of vegetation would be. The results of this study indicate that *S. alba* is a type of mangrove suitable for growing in sand-soiled soil, high salinity and inundation frequency that can be used to compare the dominance and adaptation of this mangrove type. Another reason is that the mangrove area of Denpasar rarely experiences drought at the lowest tide (Jesus *et al*., 2012).

Mangrove tree diversity is a fundamental component in maintaining the balance of aquatic ecosystems (Srivastava *et al*., 2005). According to Mandal and Joshi (2014) that climate, topography, soil, and disturbance caused by human factors can affect the structure, composition, and function of mangroves, so that the stability of mangrove ecosystems must be maintained and know their conservation status. Table 4. Shows that of the 7 species of mangrove trees, there are 5 species included in the *Least Concern* (LC) status. These species include *Soneratia alba, Rhizophora mucronata, Avicennia marina, Xylocarpus granatum,* and *Bruguiera gymnoriza.* The Least Concern category is a species that has not been given full attention by the *International Union for Conservation of Nature* (IUCN) because it is judged not to qualify as a threatened or near-threatened species (International Union for Conservation of Nature and Natural Resources, 2001). Meanwhile, *Ceriops decandra* species are species that have been categorized as *Near Threatened* (NT) or endangered by IUCN in the near future so it is very important to be preserved again by monitoring and reforestation actions. This result can be supported by the results of vegetation analysis that this species has the lowest Realistic Density value of other species (Table 3).

Furthermore, the *Thespesia populnea* species is included in the category of species that have not been evaluated (NE) by the IUCN so that it is threatened that it has no further evaluation value for this species. Overall monitoring is very important to be carried out to determine the status of vegetation species in the mangrove area. Mangrove forests are very vulnerable to the activities of surrounding communities that carry out development activities, the fisheries sector, port development and others that can be done to directly or indirectly damage mangrove ecosystems (Haerul, 2016).

Table 4 : IUCN status of mangrove vegetation in Denpasar, Bali.

Scientific name	Local name	English Name	IUCN Status
Soneratia alba	Prapat	Apple Mangrove	LC
Rhizophora mucronata	Bako	Asiatic Mangrove	LC
Avicennia marina	Api-api	Grey Mangrove or White Mangrove	LC
Xylocarpus granatum	Banang-banang	Cannonball Mangrove	LC
Bruguiera gymnoriza	Tanjang	Orange mangrove	LC
Thespesia populnea	Kuan	Pacific rosewood	NE
Ceriops decandra	Kenyongnyong	Spurred mangrove	NT

Notes: EN: Endangered; LC: Least Concern; NE: Not Evaluated; NT: Near Threatened; VU: Vulnerable.

Coastal communities that especially live around mangrove areas have livelihoods as fishermen by utilizing water resources that grow in the mangrove area. Table 5 below will explain the potential that can be developed from the mangrove ecosystem in the Denpasar Area in supporting the welfare of the surrounding community.

Table 5 : Functions and Potential of mangrove plants in the Denpasar area.

Scientific name	Function or Potency	References
Soneratia alba	Raw materials for medicinal and ships	(Dahdouh-Guebas *et al*., 2000)
Rhizophora mucronata	Prevent beach erosion, mangrove ecosystem restoration, and traditional medicine	(Adhikari *et al*., 2016; Eid *et al*., 2020)
Avicennia marina	Carbon Absorption and traditional medicine	(Barky *et al*., 2017)
Xylocarpus granatum	Traditional medicine	(Gao *et al*., 2016)
Bruguiera gymnorrhiza	Anti-inflammatory and anti-oxidative activities	(Chen *et al*., 2020; Li *et al*., 2013)
Thespesia populnea	Cellulose fiber, natural dye, Anti-inflammatory, analgesic and antipyretic and biodiesel	(Amutha *et al*., 2020; Kathirselvam *et al*., 2019; Rashid *et al*., 2011; Shah *et al*., 2011)
Ceriops decandra	Hepatoprotective activity, Antinociceptive activity, antifungal and larvicidal phytochemical	(Gnanadesigan *et al*., 2017; Kumar *et al*., 2013; Uddin *et al*., 2005)

The use of *Soneratia alba* has been widely used to meet the needs of coastal communities, one of which is as medicinal and the construction of ships in the Mida Creek (Kenya) (Dahdouh-Guebas *et al*., 2000). *Soneratia alba* can also be used as a bioindicator of pollution of the aquatic environment because of its nature which can absorb heavy metals and grow well in coral and sandy substrate. Mangrove ecosystems are also advised as a deterrent to the erosion of waters and absorbing excess carbon dioxide (Eid *et al*., 2020). Carbon dioxide (CO_2) is one of the greenhouse gases that has a major role in climate change and global warming(Shaltout *et al*., 2020). Avicenniaceae, Rhizophoraceae, and Sonneratiaceae groups that contain tannins are widely exploited for use as a flavoring material and wine color (Cruz *et al*., 2015). The tannin compound found in *Rhizophora mucronata* can be used as a natural coloring agent that can be commercially produced (Aljaghthmi *et al*., 2018).

In the field of medicine, mangroves can act as potential raw materials for traditional medicines. Some tribes in Asia and Africa use more mangrove plants as raw material for traditional medicine to treat several diseases such as hepatitis, diabetes, leukemia, dyspepsia, helminthic, and diarrhea (Saranya *et al*., 2015). Mangrove plants such as *Rhizophora mucronata, Xylocarpus granatum, Avicennia marina, Bruguiera gymnorrhiza, Thespesia populnea,* and *Ceriops decandra* can also be used as traditional medicines (Table 5). For example, the leaves of *Ceriops decandra* can be used in raw materials have potential as an anticancer. This can be caused due to the metabolite activity contained in this plant (Abdel-Aziz *et al*., 2016). Potential inhibition of insulin secretion by pancreatic β cells in people with type 2 diabetes is also owned by *R. mucronata* and *A. marina* because there are phytochemical contents such as tannin, alkaloids, flavonoids, saponins and high triterpenes in these plants (Barky *et al*., 2017).

Conclusion

The results showed that there were 12 plant species that were identified, and 35% of species were categorized as true mangrove species. In the sample plot, 7 mangrove species were recorded in the Denpasar mangrove forest. Denpasar's mangrove forests are dominated by *Soneratia alba* (Important Value Index) of 157% and *Rhizophora mucronota* by 52%. The diversity index is 0.65, which shows that the diversity of vegetation in the mangrove area of Denpasar is homogeneous. There are 2 mangrove species that need further monitoring based on IUCN Redlist data, namely *Thespesia populnea* and *Ceriops decandra*. Further research is needed to find out the amount of carbon storage from the

Denpasar mangrove ecosystem so that it can complement the monitoring data that has been obtained.

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