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Association Analysis of Seagrass Coverage and Human Activities in Nusa Lembongan

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Abstract. *Nusa Lembongan has high marine biodiversity, including seagrass. Seagrass is a plant that lives submerged in a marine or estuary water that functions as a nursery ground, trapping sediment, and beach protector, so it is important to know the condition of seagrass coverage, especially in Nusa Lembongan for managing the Nusa Penida Marine Protected Area. This study aimed to understand the condition of seagrass coverage and the factors influencing the existence of its ecosystem in Nusa Lembongan. According to reslut in two stations, it was found that six of the twelve types of seagrasses in Indonesia, namely Enhalus acoroides, Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata, Halodule pinifolia, and Halophila ovalis. From the two stations (LMB01 and LMB02), the total seagrass coverage was 38.10±30.98% or the medium category. The seagrass communities in the station areas were generally formed by 3 types of seagrasses; Thalassia hemprichii, Cymodocea serrulata, and Cymodocea rotundata. LMB02 has higher seagrass coverage than LMB01. The seagrass coverage is inversely proportional to the intensity of human activity.*

Keywords: *biodiversity, coverage, human activities, Nusa Lembongan, seagrass*

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INTRODUCTION

Nusa Lembongan has high marine biodiversity, one of which is seagrass. Seagrasses are Angiospermae, that live submerged in the water and grow well in shallow marine waters and estuaries. Seagrasses are not true grasses. Although they are all monocotyledons, they do not have a single evolutionary origin but are a polyphyletic group (Short et al., 2016). Seagrass consists of leaves and sheaths, creeping stems (rhizomes), and roots that grow on the rhizome. On previous estimates, seagrasses were reported in 191 countries and six global bioregions spanning the tropical and temperate seas (Short et al. (2007) in McKenzie et al. (2020)), one of them being in Indonesia. Kuo (2007) in Sjafrie et al. (2018) explained Indonesia had 15 species of seagrasses in two families and seven genera.

Seagrass has ecological values for marine biota. It functions as place for living, source of food, sedimentation trap and absorber for currents and waves (Rahmawati et al., 2014), and contributes indirectly to coral reef populations (Verweij et al., 2018). Seagrass is a critically important food source for dugong and sea turtles (Short et al*.,* 2016) where the species are fully protected marine biota in Indonesia. That makes condition of seagrass habitats also be useful as a bio-indicator of another ecosystems (Hedley et al., 2021). In addition, the seagrass ecosystem also has an important function as a carbon sink, that sequestration in seagrass biomass will be flowed into the sediment. Carbon under the substrate is very important because it will be buried and locked in the sediment (Graha et al., 2016). Overall, the carbon sink of restored seagrass meadows, represents as an important strategy for offsetting carbon emissions and thereby mitigating climate change (Macreadie et al., 2015).

The climate change which is underway driven impacts on people and ecosystem. Yet, there exists negative social-ecological reciprocity (Kittinger et al., 2012). While seagrass meadows provide important ecosystem services for people, reciprocal anthropogenic impacts modify seagrass meadows (Unsworth et al., 2018b). Urgently, we need to focus on protecting the ecosystems and biodiversity that provide and help to remain intact in the future, and one of those is by conserving seagrass ecosystems (Unsworth et al., 2018a).

Nusa Lembongan is included in the Nusa Penida Marine Protected Area (MPA). This MPA has been established by the Minister of Marine Affairs and Fisheries of the Republic of Indonesia through Decree Number: 90/KEPMEN-KP/2018 concerning the Nusa Penida Marine Protected Area, Klungkung Regency in Bali Province. The main function of Nusa Penida MPA is to actualize the preservation, protection, and utilization of the fish species diversity and ecosystems in Nusa Penida waters, such as sunfish and Manta rays. Furthermore, the Nusa Penida MPA can still be used for productive economic development while adhering to the principles of environmentally friendly and sustainable.

Seagrass in Nusa Lembongan was studied using LANDSAT 8 satellite images and found that the area of seagrass beds in Nusa Lembongan is 776.600 m^2 (Pramudya et al., 2014). Formerly, Yusup and Asy'ari (2010), reported seagrass diversity among areas, these are eight species in Bali; and six species in the Jungutbatu area, of Nusa Lembongan (Alhanif, 1996). Then, Kurnia et al. (2015) identified five species of seagrass found on Lembongan Beach in Nusa Lembongan.

Seagrass meadows continue to decline in various places due to exposure to various stresses (Dunic et al., 2021; Unsworth et al., 2019). One of the causes of pressure on seagrass beds is anthropogenic factors: settlements, tourism, unsustainable fisheries, and aquaculture (Thu et al., 2012). It is estimated that high anthropogenic factors will have an impact on decreasing seagrass density and beach quality. However, presently there is still a lack of research on this association. Therefore this study aimed to know the current condition of seagrass coverage and its association to human activities in Nusa Lembongan. Furthermore, this results from this condition are then expected to be used as input for the management of the Nusa Penida MPA.

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MATERIALS AND METHODS

Site Study

This study was carried out in September 2019 in Nusa Lembongan waters, Klungkung Regency, Bali Province. This location was chosen to provide an overview of seagrass cover in areas that have high human activities compared to locations with low human activities and assisted by the presence of important ecosystems in one location (coral reef, mangrove, and seagrass). In addition, Nusa Lembongan is one of the important areas that must be monitored and is one of the target activities in 2019 by CMRMC Denpasar to assist the local government in managing marine and coastal ecosystems. Nusa Lembongan has a beach with a sloping condition of approximately 30^o. The samples were taken at two stations (Figure 1), namely Lembongan Beach (LMB01) at 8.69441, 115.44556, and Sakenan Beach (LMB02) at 8.66374, 115.45899. This coordinate was the starting point of the second (middle) transect at each seagrass monitoring station.

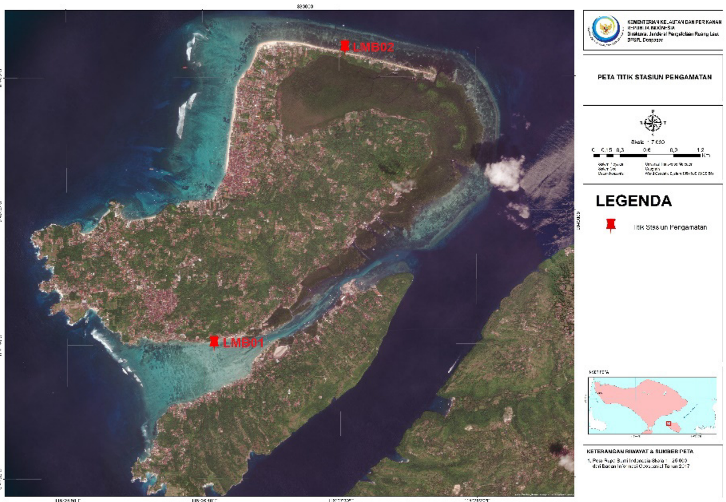

Figure 1. The map of observation station

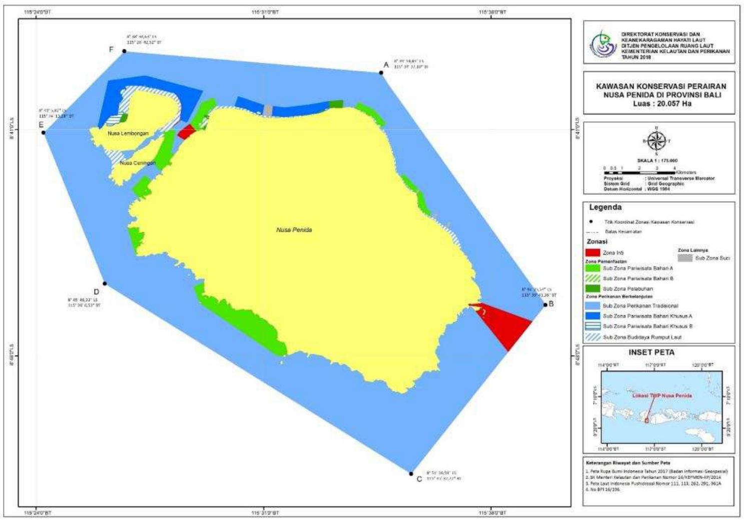

Figure 2. Map of the Nusa Penida Marine Protected Area (The Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia, 2018)

Sampling Method

This research used several tools like pipe transects with size of 0.5 x 0.5 m^2, tape measure with length of 100 m, underwater camera, notepad, and stationery. The method for collecting the seagrass coverage data was referred to in the Seagrass Monitoring Guidebook by Rahmawati et al. (2014) (Figure 3).

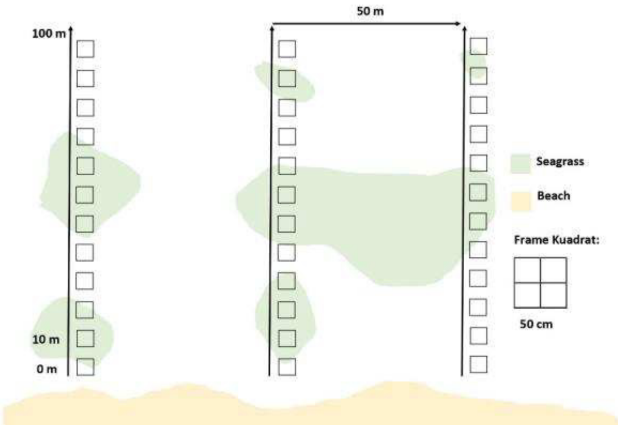

Figure 3. Seagrass transect line method illustration (Rahmawati et al., 2014)

The data were collected by running a transect line parallel to the shoreline from 10 m to the first seagrass found until 100 m toward the shore. At each line transect, the seagrass ecosystem was observed with the help of a transect plot measuring 0.5 x 0.5 m^2 starting from the 0 m point and repeating every 10 m up to 100 m. At each station, the data were collected on 3 transect lines with a 50 m gap between transects. The collected data included 3 main parameters, the richness of seagrass species, total seagrass coverage, and coverage per seagrass species. In addition, environmental data were collected in seagrass ecosystems using methods on field conditions to assess factors that affect seagrass beds.

Assess of human activities used was a descriptive quantitative approach. Where this method aims to compare the activities between two stations, whether one of the activities at the station is higher or lower. Human activities measured and compared at the observation station were the presence of tourism activities, buildings, marine cultivation, and important ecosystems where these activities are refers to the activities listed in the Nusa Penida MPA (Table 4). In addition, interviews were also conducted with important figures in the area.

Data Analysis

The seagrass coverage data was inputted into a table in Microsoft Excel. The standard deviation of seagrass coverage was calculated and categorized (Table 1) according to the reference book for monitoring seagrass beds by Rahmawati et al. (2014). Furthermore, the density of *Enhalus acoroides* was also calculated and compared between stations as supporting data for seagrass coverage. This species has a large size of roots and leaves (leaves can reach a length of 1 meter according to the Indonesian Status of Seagrass 2018 Book by Sjafrie et al. (2018)) so although the number of stands is low, it can provide greater cover than other types of seagrasses, or it can be said that it is easier to make observations of this species.

Calculating seagrass coverage in one plot

Formula 1

$$Seagrass\ coverage\ (\%) = \frac{Number\ of\ seagrass\ coverage\ (4\ boxes)}{4}$$

Calculating the average seagrass coverage per station

Formula 2

$$Average\ of\ seagrass\ coverage\ (\%) = \frac{Number\ of\ seagrass\ coverage\ for\ all\ transects}{Number\ of\ plots\ of\ all\ transects}$$

Calculating seagrass coverage per species at one station

Formula 3

$$Average\ of\ seagrass\ dominance\ value\ (\%) = \frac{Total\ of\ each\ type\ of\ seagrass\ coverage\ for\ all\ plots}{Number\ of\ plots\ of\ all\ transects}$$

Calculating the average of seagrass coverage per location or island

Formula 4

$$\text{Average of seagrass coverage in a location or island (\%)} = \frac{Total\ average\ of\ seagrass coverage\ of\ all\ stations\ in\ a\ location\ or\ island}{Number\ of\ station\ in\ a\ location\ or\ island}$$

Estimation of the average of seagrass coverage

Formula 5

$$Density\ Ea\ \left(\frac{standing}{m^2}\right) = Number\ of\ Ea * \ x\ 4$$

where:
* = Number of Ea in squares of size 0.5 x 0.5 m^2
Ea = *Enhalus acoroides*
4 = the constant to convert 0.5 x 0.5 m^2 to 1 m^2

Table 1. Category of seagrass coverage

Percentage of Coverage (%)	Category
0 – 25	Rare
26 – 50	Moderate
51 – 75	Dense
76 – 100	Solid

RESULTS AND DISCUSSION

The seagrass diversity of Nusa Penida MPA were recorded in Table 2 and Figure 4. While the detail coverage of specific species was presented in Figure 5. At LMB01, the dominant seagrass is *Cymodocea rotundata* (Cr) that coverage of 17.50±24,14. While, LMB02 founded the dominant species was *Thalassia hemprichii* with a coverage of 26.01±22.44%.

Table 2. Species in all stations

Species	LMB01	LMB02
Cymodocea rotundata (Cr)	√	√
Thalassia hemprichii (Th)	√	√
Cymodocea serrulata (Cs)	√	√
Halodule pinifolia (Hp)	√	-
Halophila ovalis (Ho)	-	√
Enhalus acoroides (Ea)	-	√

For the result of coverage using standard deviation, the large standard deviation is caused by the high variation in the data. At one station, the highest data can be found at 100% cover and the lowest data at 0% cover. This discrepancy causes the calculation of the

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standard deviation to be unreasonable.

Based on this result, there are differences of seagrass diversity and its coverage. Seagrass species have characteristic habitat mainly related to their substrate. Seagrasses like muddy, sandy, clay substrates, or substrates with coral fractures and rock crevices, thus allowing some types of seagrasses to still be found in coral and mangrove ecosystems (Newmaster et al. 2011). Formerly, De Silva & Amarasinghe (2007) stated that substrate characteristics influence to the structure and abundance of seagrass in an area or region.

At the LMB02, the coverage of *Thalassia hemprichii* is higher than LMB01. This condition predicted due to substrate in the LMB02 that consist of sandy and mud. This is in accordance with Hans (1996) who stated that *Thalassia hemprichii* lives better on a slightly sandy muddy substrate, then Jiang et al. (2017) and Jiang et al. (2022) explained that *Thalassia hemprichii* grows better on coarse sand substrate or in the coral substrate. Besides *Thalassia hemprichii*, *Enhalus acoroides* also lives quite well on this type of substrate. In this study, this type of substrate was only found at LMB02 station with a very small coverage that 0.09±0.04%.

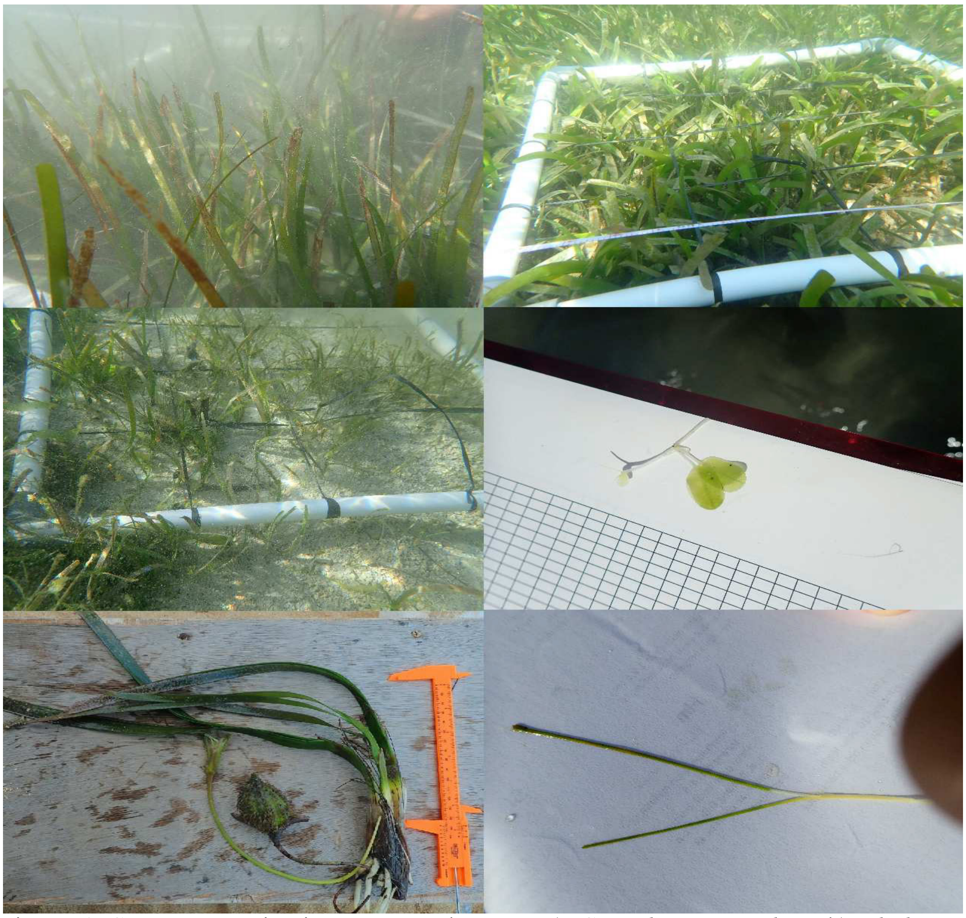

Figure 4. Seagrass species in Nusa Lembongan: a) *Cymodocea serrulate*; b) *Thalassia hemprichii*; c) *Cymodocea rotundata*; d) *Halophila ovalis*; e) *Enhalus acoroides*; f) *Halodule pinifolia*

In LMB01, *Thalassia hemprichii* has lower coverage compared to LMB02, because the substrate consists of rocky and sandy. However, *Cymodocea rotundata* had the highest coverage in LMB01 that 17.5±24.14%. This species are well grown on sand-mud or sand substrate with coral rubble in tidal areas (Corempar, 2007 *in* Faishol et al., 2016).

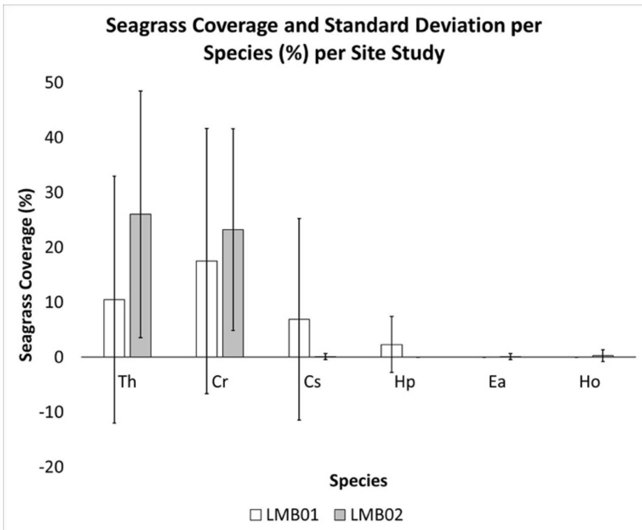

Figure 4. Distribution of seagrass at each sampling station (LMB01: Lembongan Beach, LMB02: Sakenan Beach) in Nusa Lembongan in September 2019

Furthermore, the seagrass percentage of each species and stations are presented in Figure 4. After obtaining coverage data per species, seagrass coverage was calculated at each station, with the following details: LMB01 was 31.90±32.24% and seagrass coverage in LMB02 was 44.29±28.83% (Table 3). Meanwhile, the average of seagrass coverage for all observation stations was 38.10 ± 30.98% that included in the medium category (Rahmawati et.al., 2014). This indicated that seagrass ecosystem has less adaptability and recovery from damage. So that there is need of action to increase protection from further disturbances in the future (Rahmawati, 2022) such as regulating the impact of massive human activities on seagrass ecosystems.

On quantitative descriptive observations, the results showed that the two locations have diverse human activities such astourism, ship crossing, aquaculture, and settlement (Table 4 and Table 5). Tourism activities including diving and sightseeing boat in LMB02 is higher than in LMB02. Meanwhile activities related to cafe/restaurant buildings, such as cafe/restaurant buildings, piers, and settlements found higher in LMB01. The seaweed culture activities found higher in LMB01, while capture fisheries activities were not found in both stations. Based on the Nusa Penida MPA, capture fisheries activities in particular have been accommodated in LMB02 adjoin with seagrass. As reported by de la Torre-Castro et al. (2014), seagrass habitats provided the largest number of fish and increasing economic value. It is supported Blandon & Ermgassen (2014), that seagrass habitat is of great importance as a nursery of fish species. So, it is important to arrange a special marine tourism zone in the seagrass area to achive sustainable fisheries such as using traditional tools.. In addition, other important ecosystems were found at LMB02: mangroves and coral reefs. Supriyadi et al. (2017), the mangrove ecosystem is important to maintain changes in the aquatic environment with a unique root system that protect for seagrass and coral reef ecosystems.

The existing activities at the two study sites are almost in accordance with the utilization area (Figure 2). At the LMB01 there was seaweed culture, which is already in the seaweed culture sub zone. Although at the LMB02 station, a seaweed culture subzone was also allocated, but this activity was not found during observation. Marine tourism activities in LMB02 Station were in accordance with the Special Maritime Tourism Subzone, which is located on the north side of the seaweed culture subzone. Furthermore, ferry boat activities found at LMB01 were not in accordance with the zoning. According to Figure 2, there is no special zone for port activities in this area. This activity can disturb seagrass coverage. The result and analysis in this study can be used as an input for the management of activities to suit the zoning and protect the ecosystem especially seagrass.

As one of the ecosystems that are very vulnerable to the environment, especially to the fluxes of terrestrially derived organic and inorganic materials (Quiros et al, 2017), therefore the activities originating from the mainland (human activities) will provide the inputs, and give big impact to the condition of seagrass coverage. Based on the result, human activities in LMB01 are higher than LMB02, but the seagrass coverage in LMB01 lower than LMB02. Therefore concluded, that human activities are impact to seagrass coverage, the more human activities, the lower the seagrass coverage. This pattern was also reported from Banten Bay (Kiswara, 1994). However, the relation between human activities and seagrass coverage needs to be develop especially regarding their methods. For example, from this study, provide input to the regional manager of the Nusa Penida Regional MPA.

Table 3. Comparison of the total coverage of each observation station

Station ID	**Seagrass Coverage (%)**
LMB01	31.90±32.24
LMB02	44.29±28.83

Table 4. Environmental factors qualitative observation table

Categories	**Factor Type**	**LMB01**	**LMB02**
Tourism:			
	Diving tour	-	√
	Sightseeing boat	√	√
Building:			
	Cafe/ Restaurant	√	√
	Pier	√	-
	Settlement	√	√
	Capture Fisheries	-	-
Aquaculture:			
	Seaweed	√	-
Important Ecosystem:			
	Coral reefs	-	√
	Mangroves	-	√

Table 5. Environmental factors qualitative comparison table

Categories	Factor Type	Station		
Tourism				
	Diving tour	LMB01	<	LMB02
	Sightseeing boat	LMB01	<	LMB02
Building				
	Cafe/ Restaurant	LMB01	>	LMB02
	Pier	LMB01	>	LMB02
	Settlement	LMB01	>	LMB02
	Capture Fisheries		-	
Aquaculture				
	Seaweed	LMB01	>	LMB02
Important Ecosystem				
	Coral reefs	LMB01	<	LMB02
	Mangroves	LMB01	<	LMB02

CONCLUSION

The category seagrass coverage of Nusa Lembongan categorized as medium of 38.10±30.98%. Seagrass community in this location consists of *Thalassia hemprichii, Cymodocea serrulata*, and *Cymodocea rotundata*. Human activities greatly affect the condition of seagrass coverage in Nusa Lembongan, as in this study that in the seagrass coverage LMB02 is higher than LMB01 and it is opposite to the existing increase in human activity.

AUTHOR CONTRIBUTION

S.W. was the team leader who led this study, E.Y.S. and I.G.N.A.D. wrote the manuscript, supervised and processed the data, R.L. collected, analyzed, and processed the data, Y. K.P,M.M.M.and D.G.T.B.S. helped on data collection and references.

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CONFLICT OF INTEREST

There is no conflict of interest during the research work.

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