Growth dynamics and survival of mangroves (Rhizophoraceae) seedlings in Guang-guang, Mati City, Davao Oriental, Philippines

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Abstract. The study aims to observe the growth dynamics and survival of mangroves, particularly the species that belong to the family Rhizophoraceae in Guang-guang, Mati City, Davao Oriental, Philippines. To gather the necessary data, the researchers employed the transect line method in 3 sampling stations. The result shows that there was a significant difference of seedling height during the initial and final sampling. The accumulated growth rates of the seedlings after 1 month were 5.55 cm, 6.25 cm, 5.51 cm in stations 1, 2, and 3, respectively. The total accumulated leaves after a one-month interval of sampling were 0.72, 1.19 and 0.92 in stations 1, 2 and 3, respectively. The seedlings had a total of 2-8 leaves after one month from the initial sampling. The number of leaves shows significant difference after the interval of the study, but no significant difference were observed among the stations. The general observation of the species density shows a decline and the survival rates were over 80%. The physico-chemical parameters such as temperature, pH, and dissolved oxygen of the sampled area were within normal ranges, except for salinity, which was far less than normal, ranging from 24-27 ppt. No harmful human activities that could affect the growth and recruitment of the mangroves in the area was evident, according to respondents.

Key Words: climate change, mangrove ecosystem, mangrove propagules, *Rhizophora apiculata*, survival rate.

Introduction. The Philippines is an archipelagic country consisting of 7107 islands located completely within the tropics of the southeastern coast of Asia (Long & Giri 2011). According to Myers et al (2000), the Philippines Islands are considered one of the top biodiversity "hot spot" areas of the world, supporting 1.9% of the world's endemic plants and vertebrate species. It is one of the richest diversity areas in the world (Calumpong & Menez 1997).

One of the most important components of coastal ecosystem is the mangal community (mangroves) on the landward side of the coastal zones, usually located within the intertidal zone (Cañizares & Seronay 2016). Mangroves form unique ecological environments, which provide habitats for rich assemblages of species. Thereby muddy or sandy sediments of mangroves offers home for different epibenthic, infaunal and meiofaunal invertebrates, with reservoirs within the mangroves supporting communities of phytoplankton, zooplankton and fish (Cañizares & Seronay 2016). In addition, mangrove forests provide a wide range of services and products for coastal communities, including protection from storms and large waves (Danielsen et al 2005), from coastal erosion and pollutants, but also act as nursery, feeding, and spawning grounds, and are a source fuel wood, charcoal, medicine, and timber (Lu et al 1997; Wang et al 2003; Giesen et al 2007; Ong & Gong 2013).

For the above mentioned reasons, mangrove are heavily exploited, deforestation reducing mangrove forest productivity globally (Duke et al 2007). According to Brown & Fisher (1920), the Philippine itself used to have an estimated 500000 ha of mangrove forests in 1918, but in the years between 1994-1995 it decreased to 100000 ha (Primavera 2000).

Despite its great importance, mangrove forests face a serious problem. In the Philippines, 50% of estimated mangrove deforestation can directly account for brackish-water pond development (Primavera 1995), and, despite the replanting efforts, mangrove degradation is still anticipated (Samson & Rollon 2008). The assessment of the remaining mangrove forest is essential for its protection and conservation.

This study was conducted to examine the growth dynamics and survival of mangrove seedling from the family of Rhizophoraceae in Guang-guang, Dahican, Mati City, Davao Oriental. Specifically, the study aimed to identify the different mangrove species seedling from the family Rhizophoraceae planted in the study area; measure the mangrove seedlings in the study area, determining height and number of leaves during initial and final sampling; determine the density and survival rate of mangrove seedlings in the study area; identify different anthropogenic activities affecting the growth and survival of mangrove seedlings; and determine the different physico-chemical parameters in the study area.

Material and Method

Study area. The study was conducted from April 10 to May 14, 2022, in the Mangrove Park and Nursery located at Guang-guang, Mati City, Davao Oriental, Philippines, with the geographic coordinates of 6°55'5.54"N and 126°15'33.15"E. The Mangrove Park and Nursery has an estimated area of 850 ha of generally planted mangroves along its shoreline and was declared a marine protected area within the boundaries of Pujada Bay, known as the Pujada Bay Protected Landscape and Seascape by virtue of proclamation no. 431 of July 31, 1994, by then President Fidel Ramos. Pujada Bay also supports the existence of 9 species of seagrass and 25 genera of hard and soft corals including the genera *Montipora*, *Acropora* and *Porites*. The bay also catches some rivers and streams, such as Catmonan Creek, Dawan Creek, Dilaon Creek, Mati River, Matiao Creek and Guang-guang Creek (Abreo et al 2021).

Establishment of the study area and field sampling design. A preliminary visual survey was done to assess the current status and to map out the mangrove area to be considered in the study. The perimeter of the mangrove area was measured for the establishment of the sampling plots. The transect line method was used to conduct the study. There were three transect lines, with a 50 m length and 10 m intervals between them. Three plots (10x10 m) with 10 m intervals between them were established in each transect (Figure 1).

Sampling was conducted two times, with a one-month interval between them. The first sampling was conducted on April 10, 2022, and the second sampling was conducted on May 14, 2022. Samplings were conducted during lowest low tide to facilitate easy sampling during the entire duration of the study. The number of seedlings, their height and number of leaves were recorded and calculated during the first and second sampling. Mangrove identification was conducted up to species level and the local names were used to facilitate understanding among local communities. Mangrove identification was carried out based on Calumpong & Menez (1997) and Primavera et al (2005). Mangrove seedlings were selected using the criteria set by Biddick et al (2005), according to which mangroves under 1 m height are classified as seedlings. Only mangroves that belonged to the family *Rhizophoraceae* were considered in the study.

All individual mangrove seedlings found in each quadrat were counted and density and relative abundance were calculated using the formula of Odum (1971):

$$\text{Density(D)} = \frac{\text{Number of seedlings of the same species}}{\text{area (m}^2\text{)}}$$

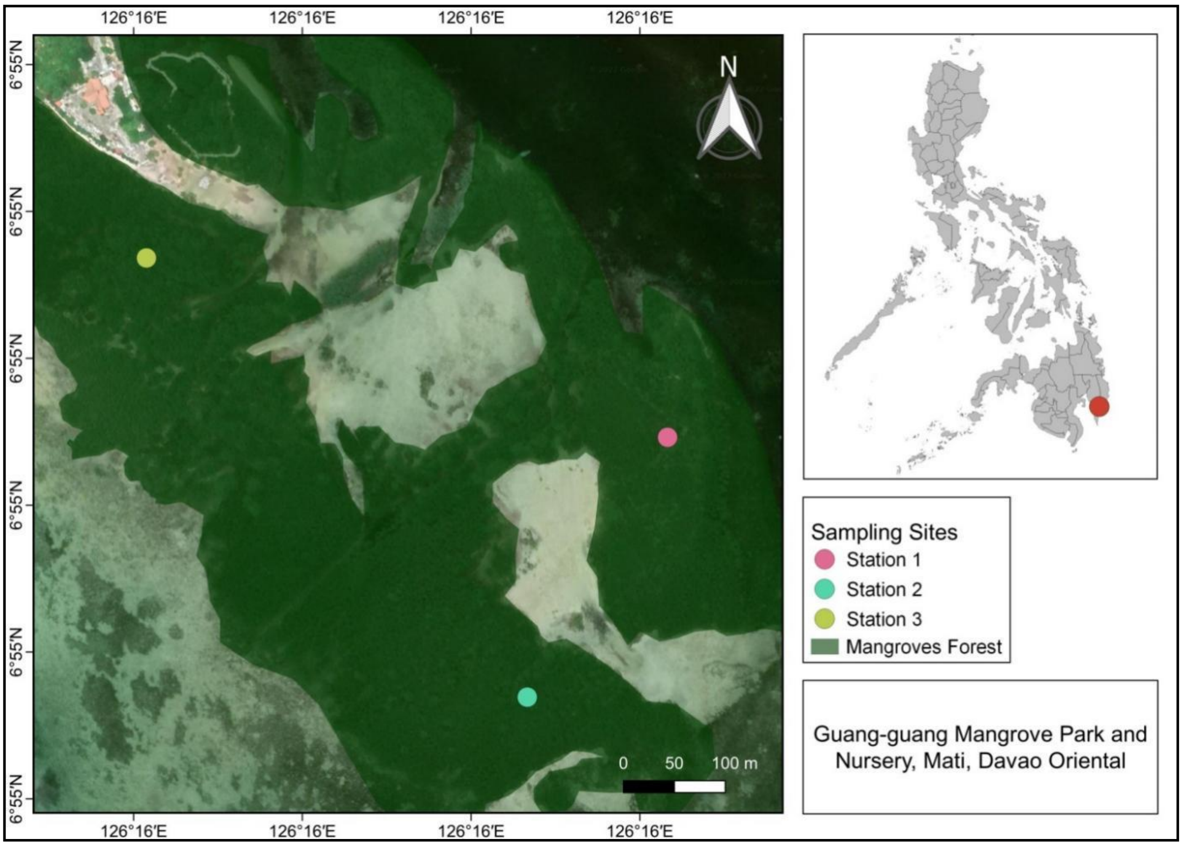

Figure 1. Map of the study area showing the Mangrove Park and Nursery of Guang-guang, Dahican, Mati City, Davao Oriental.

Growth and survival of mangrove seedlings. To determine the growth of mangrove seedlings, the individual stem was measured using a tape measure, from the base to the tip of the shoot system. The leaves of each seedling were also counted to determine their development every mangrove stand. The individual number of mangroves of each species belonging to the family Rhizophoraceae was identified during the first and second sampling to determine the survival rate (Pacyao & Llameg 2018). A purposive survey with 20 local respondents using a self-structured questionnaire was carried out to determine the anthropogenic activities that could impact the mangrove seedlings survivability in the area. The survival rate of mangroves was calculated using the following equation:

$$\text{Survial Rate} = \left(\frac{\text{final sampling}}{\text{inital sampling}}\right) \text{x } 100$$

Physico-chemical parameters. Temperature, dissolved oxygen (DO), salinity, pH and substrate type, parameters were determined with the use of a digital thermometer, digital DO meter, refractometer, pen type pH meter, and soil sieve method for the substrate, respectively.

Statistical analysis. The analysis of variance (ANOVA) was employed to determine if significant differences existed in the density and abundance of mangrove seedlings in the study area. When significant differences were observed, Tukey's test was used to specifically determine the pair of data sets with differences. The analyses were carried out in Microsoft excel 2010 and IBM SPSS 20.

Results and Discussion

Mangrove species in the study area. Mangrove seedlings found in the study area belonged to only one species, *Rhizophora apiculata*, locally known as "bakhaw lalaki" across all sampling stations. Based on Primavera et al (2005), *R. apiculata* is a species of mangrove popular in mangrove rehabilitation programs due to its availability and fast growth of propagules. This species is commonly found in sandy-muddy substrate areas and often found in the outer seaward zone of a mangrove forest (Figure 2).

R. apiculata is commonly found in the muddy coast of the Philippines, like in Panay (Primavera et al 2005), Davao region (Pacyao & Llameg 2018; Pacyao & Barail 2020; Abreo et al 2021), Oriental Mindoro (Raganas et al 2020) and Eastern Samar (Quevedo et al 2020). This mangrove species plays an important role in a mangrove ecosystem, since it helps improve water quality, supporting the growth of invertebrates like mud crabs (*Scylla serrata*) and mangrove clams (*Pegophysema philippiana*) (Primavera et al 2002; Dai et al 2020; Bersaldo et al 2023). Ariyanto et al (2021) indicate that *R. apiculata* is also capable of accumulating heavy metals like lead, which is toxic to the environment and is highly hazardous for human consumption. The aspects that propose this mangrove species for rehabilitation projects are its have high regeneration rate, high retention capacity of contaminants and contribution to the rapid increase of the mangrove forest productivity (Nguyen et al 2020; Poungparn et al 2020; Raganas et al 2020).

Figure 2. Mangrove areas in Guang-guang, Dahican, Mati, Davao Oriental (mangrove seedlings of *Rhizophora apiculata*, locally known as "bakhaw lalaki").

Mangrove seedling height and number of leaves. Mangrove species of the family *Rhizophoraceae* are popular in mangrove planting activities also because of the comfort in planting and the availability of its plant propagules (Primavera et al 2005). Based on the results of the study, seedling height was significantly different between the initial and final sampling ($p<0.05$). However, no significant difference was found between sampling stations ($p>0.05$). The mean height of mangrove seedlings increased after one month. During the initial sampling, stations 1, 2 and 3 had mangrove seedling mean heights of 37.27, 38.77 and 38.25 cm, respectively. In the final sampling, stations 1, 2 and 3 had mangrove seedling mean heights of 42.82, 45.03, and 43.73 cm, respectively, with accumulated growths of 5.55, 6.25 and 5.51 cm, respectively (Table 1).

Table 1

Final and initial mean±SD heights of mangrove seedlings in a month

	Final sampling		Initial sampling		
	Height (cm)	*Mean height (cm)*	*Height (cm)*	*Mean height (cm)*	*Accumulated growth*
Station 1	27-56	42.82±7.3[a]	22-49	37.27±7.1[b]	5.55
Station 2	31-56	45.03±7.2[a]	23-49	38.77±7.6[b]	6.25
Station 3	32-55	43.76±6.5[a]	25-49	38.25±6.9[b]	5.51

Note: different superscripts denote significant differences (p<0.05).

The average monthly growth increment of *R. apiculata* seedlings was in consonance with the results of Hastuti & Hastuti (2018), who reported a weekly growth up to 2 or 8 cm in a month, with a conclusion that this species is a fast-growing species if planted in an appropriate location. Given its fast-paced growth, this mangrove is also one of the most productive trees among all mangrove species (Sadono et al 2020). Other studies state that *R. apiculata* thrives in less saline waters, especially in creeks and along riverbanks (Primavera et al 2005; Auni et al 2020). The mangrove seedlings planted in the study area grew fast, as the bay has multiple freshwater tributaries.

Mangrove rehabilitation is widespread in the Philippines, projects such as the Philippine National Aquasilviculture Program (PNAP) of the Bureau of Fisheries and Aquatic Resources that has commenced in late 2010, which is one of the core projects of the government in addressing climate change and food resiliency by increasing the fish catch of the fishermen and increasing the supply of mud crabs together with the mangrove friendly aquaculture project (Pacyao & Llameg 2018; Pacyao & Barail 2020). Commonly, mangrove rehabilitation efforts are made by planting mangrove seedlings by batch (Loughland et al 2020), the success of a certain mangrove conservation program laying in the selection of species being planted, in a concrete plan on management and evaluation, as well as in incentives for local communities (Hai et al 2020).

The number of leaves developed in one mangrove seedling was an indication of its growth and maturity, as leaves contain photosynthetic organelles (Goldberg & Heine 2021). The number of leaves during the initial and final sampling is presented in Table 2.

Table 2

Final and initial mean±SD number of leaves on mangrove seedlings in a month

	Final sampling		Initial sampling		
	Number of leaves	*Mean number of leaves*	*Number of leaves*	*Mean number of leaves*	*Mean accumulated number of leaves*
Station 1	2-7	4.10±1.4[a]	2-6	3.38±1.04[b]	0.72
Station 2	2-7	4.61±1.3[a]	1-6	3.42±1.2[b]	1.19
Station 3	2-6	4.33±1.4[a]	2-6	3.41±1.1[b]	0.92

Note: different superscripts denote significant differences (p<0.05).

The lowest mean number of leaves in the initial sampling was in station 1, with 3.38 and 2-6 leaves per seedlings, while station 2 presented the highest mean number of leaves, with 3.42, and 1 to 6 leaves per seedling. During the final sampling, station 1 presented the fewest leaves, with the mean number of 4.10. Station 2 had the highest mean number of leaves, with 4.61 and 2-7 leaves per seedling. The total accumulated leaves after one month was 0.72, 1.19 and 0.92 in stations 1, 2 and 3, respectively, and have a total 2-8 leaves. There were significant differences observed for the number of leaves between the initial and final sampling ($p<0.05$). However, there were no significant differences observed in the mean number of leaves among the three sampling stations ($p>0.05$). The results in terms of number of leaves developed after one month of sampling was supported by the study of Hastuti & Hastuti (2018), conducted in Mangunharjo Village, Tugu, Semarang, Indonesia, from March 2015 to September 2016, with *Rhizophora mucronata* being studied. The study states that there were 0–2 leaves developed per week. Mangrove seedlings planted in open areas with the availability of sunlight develop more leaves than those planted under the canopy (Goldberg & Heine 2021). *Rhizophora* species are fast growing mangroves, especially if they are exposed to sunlight and have inputs of fresh water in the area (Erftemeijer et al 2021). Mangrove leaves usually grows in pairs. However, based on the practical data in the study, there were mangrove seedlings with an odd number of leaves, this observation being common when there is the possibility of predation by crabs and anthropogenic activities in the vicinity (MacKenzie et al 2020; Pacyao & Barail 2020).

Mangrove density and survival rate. The number of mangrove seedlings in sampling stations was counted during the initial and final sampling. There were significant differences in the mean density of mangrove seedlings between initial and final sampling, and among all the three sampling stations ($p<0.05$). The density and survival rate of mangrove seedlings is presented in Table 3.

Table 3

Mangrove seedling density and survival rate

	Station 1		*Station 2*		*Station 3*	
	Initial	*Final*	*Initial*	*Final*	*Initial*	*Final*
Number of seedlings	25	22	63	55	92	77
Density (n m^{-2})	0.028^{a}	0.024^{b}	0.070^{c}	0.061^{d}	0.102^{e}	0.086^{f}
Survival rate (%)	88		87.30		83.70	

Note: different superscripts denote significant differences ($p<0.05$).

Station 1 had the lowest density during initial and final samplings, with 0.028 n m^{-2} and 0.024 n m^{-2}, respectively, while station 3 had the highest density, 0.102 n m^{-2}, during initial sampling, and 0.086 n m^{-2} during final sampling. During the final sampling, the overall finding in the sampling area in terms of density was that mangrove seedling density was declining. The low density in station 1 occurred because the station was an area frequently gleaned and located in the narrow opening of the bay, facilitating faster water current. The high density of mangrove seedlings in station 3 was driven by the robust protection of the Department of Natural Resources (DENR) in the vicinity. The survival rate of mangrove seedlings in station 1 was 88%, the highest between sampling stations, followed by station 2 with 87.30%, and station 3 with 83.7%.

The mangrove density is critical to certain coastal areas as it helps in alleviating sediment accretion (Rizal & Anna 2020), since they have the capacity to adapt even during a partial sediment burial (Okello et al 2020). The density of mangrove seedlings planted in the mangrove area of Guang-guang, Dahican, Mati City, Davao Oriental was low during final sampling (0.024-0.086 n m^{-2}). This result was opposite to the outcome of the study of Sreelekshmi et al (2020), since the mangrove seedlings planted in the study area were of only one species, *R. apiculata*, while the study being compared had highly diverse mangroves (*Rhizophora mucronata*, *Ceriops tagal*, *Avicennia marina*), as a high diversity promotes better growth and survival. The mangrove seedlings were vulnerable to the impacts of climate change, like sea level rise that results in the increase of tidal flow of seawater in the mangrove ecosystem. Short seedlings with a height under 80 cm and less dense are easily damaged due to drowning, and uprooted due to strong water currents during the change of tide (Lovelock et al 2015; Chang et al 2020; Cinco-Castro & Herrera-Silveira 2020; Vanderklift et al 2020).

Mangrove rehabilitation became popular in the tropical region after reports that large swaths of mangrove forest had vanished and that mangrove cover around the world had been dwindling (Camacho et al 2020). The survival rate of mangrove seedlings in this study was high (above 80%). This result was comparable to the study of Hilmi et al (2022), with survival rate ranging from 55.4 to 90%, partly due to water parameters like low salinity, in which *Rhizophora* species grow faster (Mangora 2016; Singh 2020; Hilmi et al 2022). Other than low salinity, enhanced carbon dioxide concentration in the atmosphere may also play a role for a successful establishment of mangrove seedlings. However, exposure to herbivory organisms was one of the major problems when dealing with mangrove seedling survival (Manea et al 2020). Despite enormous attempts to preserve the mangrove population in nature through conservation and replanting, the latter frequently fails due to inadequate project implementation and evaluation, as well as minimal to non-existent stakeholder participation (Fickert 2020; Hai et al 2020). Moreover, the greatest threat towards mangrove survival is the extent of anthropogenic activities that co-exist wherever there are mangroves present like gleaning or harvesting of bivalves (Primavera et al 2002), conversion of mangrove areas to residential units, fishponds, boat ports, improper waste disposal areas, grazing of stray animals (Pacyao & Barail 2020).

Anthropogenic activities. Mangroves adapt well to natural stressors like temperature, salinity, anoxia, and UV. However, living near their tolerance limits, they may be especially sensitive to disturbances caused by human activity (Kathiresan & Bingham 2001). Their proximity to population centers make them favorable for sewage disposal. Mangroves have suffered from industrial effluents, habitat damage due to human encroachment, freshwater diversion for agriculture, and land reclamation (Ellison & Farnsworth 1996). Other anthropogenic threats to mangroves are dredging and filling for residential canals, clear-cutting for human development (Gilman et al 2008), and pollution from oil spills and herbicides from upstream industrial areas (Gelcich et al 2014).

The survey did not reveal any human activity that could negatively affect the mangroves. According to the respondents, they have never encountered any trace of illegal anthropogenic activities in the area (Table 4).

Table 4

Protection and anthropogenic stress to mangroves in the area

Characteristics		*Respondents*	
		N=20	*%*
Active organization/government agency that protects mangrove in the area	DENR	20	100
	others	0	0
Presence of Bantay Dagat	Yes	20	100
	No	0	0
Anthropogenic threats to mangroves	Dredging	0	0
	Filling	0	0
	Diking	0	0
	Industrial effluents	0	0
	Oil spills	0	0
	Others	0	0
	None	20	100

This result was mainly subjected to the implementation of the policy and guidelines for the conservation of the fauna and flora in the area, including mangroves. Additionally, the presence of bantay dagat, which is a community-based law enforcement organization in the Philippines that recruits fishermen from coastal barangays or towns to assist in the enforcement of laws against illicit fishing in coastal waters (SSG Advisors 2016) has secured the area from the intrusion of illegal and destructive human activities (Table 4). This survey supported the aforementioned high survival rate of mangrove seedlings in the area. The absence of the transgressors may have favored the recruitment and growth of the seedlings in each station.

Physico-chemical parameters. The majority of mangrove forests are found in the tropics, where they have suitable environmental conditions. The growth and development of mangroves are affected by the parameters in the area, as there were species that had specific requirements. (Mangora 2016; Manea et al 2020; Okello et al 2020; Wang et al 2020). In the mangrove environment, physico-chemical factors have a great influence on the structural development and productivity of the ecosystem (Das et al 2019). In this study, the temperature ranged from 32-34°C in all sampling stations, the pH from 6.81-7.23, salinity from 24-27 ppt, and DO ranged from 5.58-6.02 mg L^{-1} (Table 5).

Table 5

Physico-chemical parameters in the study area

	Temperature	*pH*	*Salinity*	*Dissolved oxygen*	*Substrate type*
Station 1	34°C	7.04	26 ppt	5.83 mg L^{-1}	Sandy mud
Station 2	32°C	7.23	27 ppt	5.58 mg L^{-1}	Sandy mud
Station 3	33°C	6.81	24 ppt	6.02 mg L^{-1}	Sandy mud

Most of the parameters are in accordance to the set standard provided by the DENR in the administrative order no 2016-08 class SC representing marshy and mangrove areas which are declared as fish and wildlife sanctuary, where the set standard temperature ranges from 25-31°C, pH from 6.5-8.5 and DO has a minimum of 5 mg L^{-1} (DENR 2016). According to Picardal et al (2011), the normal salinity for the coastal waters ranges from 33-35 ppt. The deviation of the salinity we obtained could be attributed to the rain prior to the measurements of the physico-chemical parameters. The substrate type of the site is sandy mud, which is a common ground for the mangrove species *R. apiculata* (Primavera et al 2005).

Conclusions. Guang-guang, Dahican, City of Mati, Davao Oriental is a favorable area for the growth of mangrove seedlings. The physico-chemical parameters in this location are within the normal and tolerable ranges for mangroves. Moreover, the active bantay dagat and DENR help in keeping the area free of anthropogenic stress for mangroves. Since this study has limitations, the proponent recommends the following for future studies: establishing more sampling stations to provide a clearer picture of the growth dynamics and survival rate of mangroves in the area; considering other environmental parameters in the assessment of the growth dynamics and survival rate of mangroves in the area; correlating the environmental parameters and anthropogenic activities in the bay with the growth dynamics and survival rate of mangroves in the area.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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