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ROLE OF ANTHROPOGENIC CANOPY GAPS ON NATURAL REGENERATION PATTERN OF MONOSPECIFIC *CERIOPS TAGAL* IN RAKAWA LAGOON, SRI LANKA

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Abstract

Mangroves are distinctly dominated in tropical and subtropical areas as special kind of trees, palms, shrubs, vines and ferns. Ceriops tagal is one kind of mangrove species which shows monospecific distribution in Rakawa lagoon in Sri Lanka. There are certain factors which influence the natural regeneration pattern of Ceriops tagal. Light intensity is one of the factors which penetrates through canopy gaps and regulates the growth of seed, seedling and sapling and these canopy gaps are resulted mainly due to anthropogenic canopy eradication. However, the studies on the influence of man-made canopy gaps on natural regeneration pattern of mangroves are limited in Sri Lanka. Therefore, current study was carried out in Rakawa Lagoon in July 2014 to estimate the regeneration pattern of Ceriops tagal by the *means of mean seedling, sapling densities and live and dead seed densities in open canopy sites with regard to closed canopy sites. Finally, to compare the mean density values of Seedling plus sapling obtained in July 2013 to get the overall knowledge on the effect of canopy gap on regeneration pattern of Ceriops tagal. Consequently mean density of seedling plus sapling were taken as regeneration class 1 and height of seedlings and saplings and the number of live and dead seeds were documented from randomly selected three homogenous plots ,(4m^2 x 3) from open canopy sites and three homogenous plots (4m^2 x 3) from closed canopy sites. Two –Sample T- test and Paired T-test of "MINITAB 16 software" were used to analyze and compare the data. Mean density of regeneration class 1 in open canopy sites was significantly higher p=0.02 (p<0.05) than closed canopy sites. Hence canopy gaps play major role in enhancing the natural regeneration and increasing the survivability of Ceriops tagal species. Output of this study can be used for mangroves conservation in Sri Lanka.*

Keywords

Anthropogenic, Canopy Gap, *Ceriops Tagal*, Mangroves, Sri Lanka

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1. Introduction

Mangroves exist as trees, palms, shrubs, vines and ferns with high biological productivity and dominate distinctly in tropical and subtropical areas along the coastal belts of mudflats, river banks and estuaries with the association of brackish water margins between the land and the sea (Polidoro *et al.*, 2010; Giri *et al.*, 2011). Some species of mangroves have well developed knee root systems to anchor in soil while others have aerial roots to intake atmospheric oxygen (Alongi, 2002, 2009) Thick waxy leaves, hairy leaves and spiny leaves of different mangrove varieties prevent the water lost in tempered environment (Peter & Sivasothi, 2002). There are around sixty species of true mangroves identified in the world and twenty one species are accommodated along the coastal belt of Sri Lanka (Thisera & Kumara, 2009). *Ceriops tagal* is considered as common mangrove species (Duke *et al*., 2010) which can be found along streams to intermediate estuarine and coastal areas in the mid and high intertidal regions. It is hardy and shade intolerant species distributed in East Africa, India, Malay Peninsula and southern China (Duke *et al.*, 2010; Giri *et al.*, 2011). Canopy cover limits the amount of sunlight that reaches to the forest floor resulting insufficient growth or mortality of juveniles (Kneeshaw & Bergeron, 1998) while canopy gap created by the destruction or death of mature tree boost both biotic and abiotic resources by altering ecological process. (Denslow, 1998; Zhao *et al*., 2006) Canopy gap in the mangroves forest is classified into six different phases such as No gap, Initiation, Opening, Recruitment, Filling and Closure (Duke, 2001; Amir & Duke, 2008). On the contrary, the studies on natural regeneration pattern of *Ceriops tagal* under the effect of open canopy sites are limited in Sri Lankan context and this study was done to fill up this study gap for better understanding of mangrove forest recovering process in order to support the mangrove forest conservation in Sri Lanka.

1.1 Research Objectives

Main objectives of the research were to (a) compare the mean densities of seedlings and saplings in open canopy sites with closed canopy sites (b) to compare the mean dead and live seed densities in open and closed canopy sites (C) to compare the mean densities of seedling and sapling in open and closed canopy sites in July 2013 with July 2014 (d) to compare the mean dead and live seed densities of open and closed canopy sites in July 2013 with July 2014 and finally to find the role of the canopy Gaps on natural regeneration pattern of *Ceriops tagal* in order to provide conservation and management implications for Sri Lankan Mangrove.

2. Materials and Methods

2.1 Research location and Description

Rakawa Lagoon is located in the coastal belt of Hambanthota district in the southern province of Sri Lanka which receives annual rainfall between 1270-1910 mm (IUCN, 2004). A monospecific *Ceriops tagal* forest in Rakawa Lagoon was selected for the study in the month of July 2013 and 2014. Six ($4m^2$) plots were randomly selected including three plots in open canopy site (caused by tree cutting) and another three plots in adjacent undisturbed closed canopy site (Figure 01 & 02).

Figure 1: *Rekawa in Sri Lankan map (Source- Google map)*

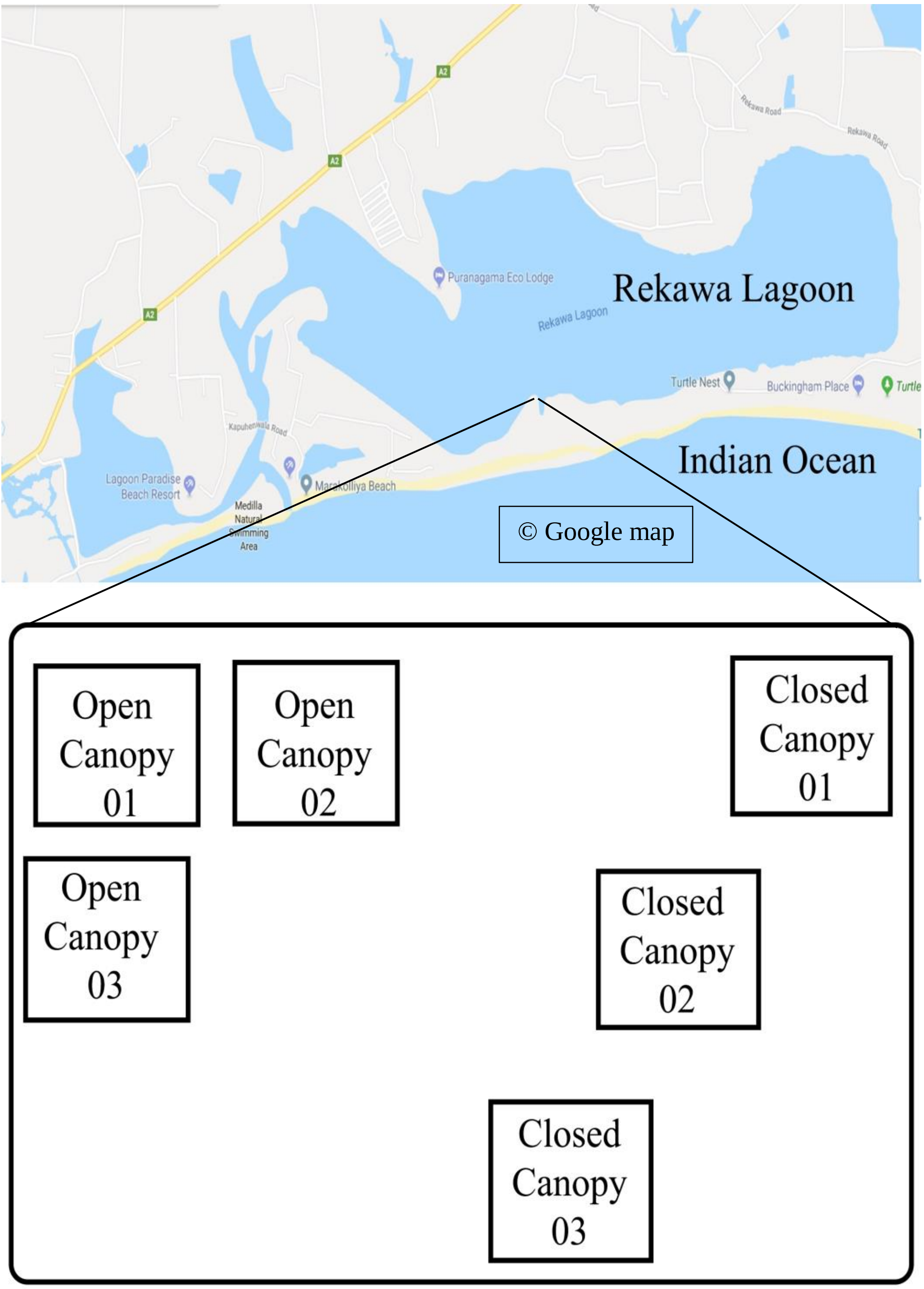

Figure 2: *The map of study site (Monospecific Ceriops tagal forest in Rekawa)*

2.2 Data Collection

Heights of seedlings and saplings and the number of dead and live seeds in each plot were measured using meter rulers in the month of July, 2013 and 2014. Seedling and sapling were taken as regeneration class 01 and all collected data were quantified into four height classes (HC): HC 1 (Seedlings less than 30 cm), HC 2 (Seedlings between 30-40cm) HC 3 (Saplings 40-50cm): HC 4 (Saplings between 50-150 cm).

2.3 Statistical Analysis

Data were summarized in "MICROSOFT EXCEL 2007". Two –Sample t- test and Paired t-test in MINITAB 16 statistical software were used to compare (1) the mean densities of live and dead seeds (2) mean seedling and sapling density of each height classes and (3) the parameters of two consecutive years between the two sites.

3. Results

According to the results, the density of the Regeneration class 01 in open canopy sites (113.2±19.4 m^{-2}) was significantly higher ($P<0.05$) than closed canopy sites (26.0±9.9 m^{-2}) (Two sample-t-test) (Table 01). There was no significant difference between the mean densities of open (22.8±9.6 m^{-2}) and closed (22.3±6.2 m^{-2}) canopy sites for the height class 1(<30cm) ($p>0.05$: two sample t-test), But the height class 2 (30-40cm) showed significantly higher seedling density in open canopy site (52.4±14.2 m^{-2}) than closed canopy site (3.7± 3.8 m^{-2}) ($p<0.05$: two sample t-test). There were no saplings recorded in height class 3 (40-50 cm) and 4 (>50 cm) in the closed canopy sites but open canopy site showed mean densities of (27.3±3.9 $m^{-2)}$ for height class 3 and (10.6±2.6 $m^{-2)}$ for height class 4. (Two sample t-test; Table 2).

Table 1: *Mean densities (number m^{-2}) of Regeneration class 01 of Ceriops tagal in open and closed canopy Sites with Standard Deviations (July 2014)*

	N	Mean
Open Canopy	3	113.2±19.4
Closed Canopy	3	26.0±9.9

Table 2: *Mean Density (number m^{-2}) and the Standard Deviation of each Height classes of the two sites (July 2014)*

	HC 1 (<30cm)	HC 2 (30-40cm)	HC 3 (40-50cm)	HC 4 (50<cm)
Open Canopy	22.8±9.6	52.4±14.2	27.3±3.9	10.6±2.6
Closed Canopy	22.3±6.2	3.7± 3.8	0	0

3.1 Live and dead seed in July 2014

Mean Density of live seed in open canopy sites (42.8±18.6m^{-2}) was not significantly different ($p>0.05$) from the closed canopy site (8.3±7.1 m^{-2}) (Two sample t-test) (Table 3).

Mean Density of the Dead Seed of open canopy sites (23.8±10.3 m^{-2}) was not significantly different (P>0.05: two sample t-test) from the closed canopy sites (51.9±23.6 m^{-2}) (Two sample-t-test) (Table 4).

Table 3: *Densities (Mean±SD) of live seed between the two sites (number m^{-2})*

Site	N	Mean
Open Canopy	3	42.8±18.6
Closed Canopy	3	8.3±7.1

Table 4: *Densities (Mean±SD) of dead seed in open and closed canopy sites (number m^{-2})*

Site	N	Mean
Open Canopy	3	23.8±10.3
Closed Canopy	3	51.9±23.6

Comparative results of two studies documented in 2103 and 2014

Table 5: *Mean Densities of Ceriops tagal regeneration class 01 in open and closed canopy Sites with Standard Deviation*

	July 2013		**July 2014**
Site	N	Mean±SD	Mean±SD
Open Canopy	3	112.7±16	113.2±19.4
Closed Canopy	3	10.8±3.8	26±9.9

The Mean densities of regeneration class 1 in open canopy Site in 2013 (112.7±16.0 m^{-2}) was not significantly different (P>0.05: Paired-t-test) from the open canopy Site in 2014 (113.2±19.4 m^{-2}). The Mean densities of regeneration class 1 in closed Canopy Site in 2013 (10.1±3.8m^{-2}) was not significantly different (P>0.05: Paired-t-test) from the closed Canopy Site in 2014 (26.0±9.9 m^{-2}) (Table 05).

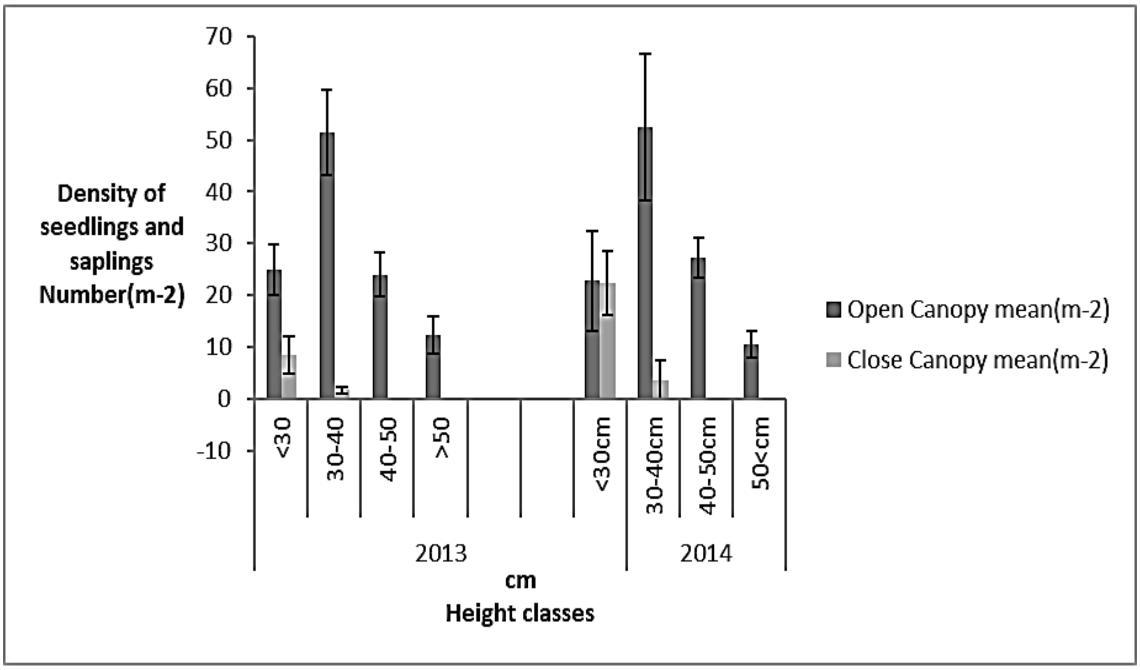

Figure 3: *Density (Mean±SD) of Seedling and Sapling of each height classes in open and Closed Canopy sites in July 2013 and July 2014*

Mean densities of height class 2 (30-40cm) height class 3(40-50cm) and height class 4 (>50 cm) showed no significant different between 2013 and 2014 except for the values obtained for height class 1 (<30 cm) in which, mean seedlings density of closed canopy sites was significantly higher P=0.03(p<0.05) in 2014 (22.3±6.2 m^{-2}) than 2013 (8.4±3.7 m^{-2}) (Paired-t-test; (Figure 3).

Table 6: *Density of Live and dead seed (Mean±SD) in 2013 and 2014*

	2013		**2014**	
	Live	Dead	Live	Dead
Open canopy	40.3±15.9	24.5±5.5	42.8±18.6	23.8±10.3
Closed Canopy	33.8±22.1	13.5±8.7	8.3±7.1	51.9±23.6

Mean densities of live seed showed no significant different between 2013 (40.3±15.9 m^{-2}) and 2014 (42.8±18.6 m^{-2}) for the open canopy sites (p>0.05), mean densities of dead seed showed no significant different between 2013 (24.5±5.5 m^{-2}) and 2014 (23.8±10.3 m^{-2}) for open canopy sites (p>0.05), mean densities of live seed showed no significant different between 2013 (33.8±22.1 m^{-2}) and 2014 (8.3±7.1 m^{-2}) for closed canopy sites (p>0.05), mean densities of dead seed showed no significant different between 2013 (13.5±8.7 m^{-2}) and 2014 (51.9±23.6 m^{-2}) for closed canopy sites ($p>0.05$), (Paired-t-test; Table 06).

4. Discussion

The current study showed that the monospecific distribution of *Ceriops tagal* forest indicated no competition from any other flora species and hence the increased light intensity through canopy gap could be the major factor of growth of newly recruited juveniles in the canopy gap thus seedling and sapling distributed under the anthropogenic open canopy site was significantly higher than closed canopy site. Thus, the density of the Regeneration class 01 in the open canopy sites (113.2±19.4 m^{-2}) was significantly higher ($P<0.05$) than the closed canopy (26.0±9.9 m^{-2}) sites.

Results indicated that, there were no significant differences between the mean densities of open (22.8±9.6 m-2) and closed (22.3±6.2 m-2) canopy sites for the height class 1(<30cm) ($p>0.05$: two sample t-test) thus the present research stated that the occupation of seedling and sapling was not enhanced by the seed concentration. Hence the growth rate of seedling and the sapling could be highly influenced by the light penetration through canopy gaps (Denslow, 1998; Sen et al., 2008). The Height class 2 (30-40cm) showed significantly higher seedling density in open canopy site (52.4±14.2 m^{-2}) than the closed canopy site (3.7± 3.8 m-2) ($p<0.05$: two sample t-test) and there were no saplings recorded in height class 3 (40-50 cm) and 4 (>50 cm) in the closed canopy sites, this could due to lack of sunlight for further growth. Recruited seedlings could be deteriorated due to lack of sunlight in closed canopy sites (Denslow, 1998; Gravel *et al*., 2010). Gap formation changes both biotic and abiotic settings with rapid increase of light penetration on the mangroves floor with the decline of dead mangroves and the growth of fresh faced mangroves (Aldrie & Norman, 2008) hence the height class 3 and 4 in the open canopy site showed mean densities of (27.3±3.9 m^{-2}) and (10.6±2.6 m^{-2}) respectively.

Mean Density of live seeds in the Open canopy sites (42.8±18.6m^{-2}) was not significantly different ($p>0.05$: two sample t-test) from the closed canopy site (8.3±7.1 m^{-2}) (Table 05) since the regeneration of *Ceriops tagal* could not be enriched by the concentration of seed in open and closed canopy sites and canopy gaps were not responsible for the dispersal of seed. Mean Density of the dead Seed of open canopy sites (23.8±10.3 m^{-2}) was not significantly different ($P>0.05$: two sample t-test) from the closed canopy sites (51.9±23.6 m^{-2}). Increased of mean density of dead seed in open canopy sites of Rakawa mangrove forest could be caused by human trampling during wood cutting.

Highest mean density in the open canopy site was recorded for the height class 2 (30-40 cm) for both years while the highest density in the closed canopy site was recorded for the height class 1 (<30 cm) for both years (Figure 02). In the closed forest arrangement, the light availability reduced by the canopy cover prevents the further growth and survivability of recruited seedlings (Kneeshaw & Bergeron, 1998). Decreased in light intensity increases the mortality rate of shade intolerant species whilst canopy opening enhances the growth rate of shade intolerant species (Gravel *et al*., 2008, 2010) *Ceriops tagal* could be considered as shade intolerant species and light intensity through canopy gap increases the natural regeneration of *Ceriops tagal* species in Rakawa mangrove forest.

5. Conclusions and Recommendations

The Increase of gap creation mainly due to the natural phenomena like storms (Amir & Duke, 2008) however the rate of natural regeneration pattern of monospecific *Ceriops tagal* species in Rakawa lagoon was greatly influenced by the formation of gap due to anthropogenic activities than natural phenomena hence open canopy sites showed mean densities of ($112.7 \pm 16m^{-2}$) in July 2013 and ($113.2 \pm 19.4m^{-2}$) in July 2014 for regeneration class 01 while adjacent undisturbed forest showed lower mean densities ($10.8 \pm 3.8m^{-2}$) in July 2013 and ($26 \pm 9.9m^{-2}$) in July 2014 for regeneration class 01. Therefore, we can reject the null hypothesis and accept the alternative hypothesis as there was a significant increase in mean densities of seedlings and saplings of anthropogenic open canopy site than undisturbed closed canopy sites ($p<0.05$). Therefore we can recommend that natural regeneration is greatly increased due to anthropogenic eradication. However this was only preliminary study and only six ($4m^2$) plots were selected due to limited time factor. Therefore, for the precise and solid evidence, this research need to be carried out to study the continuous regeneration pattern of mangroves from seedlings to young trees by increasing the number of plots for different types of mangrove species for prolong time period with regard to the density distribution at the center and the margins of the open and moderately open canopy sites to set up continuous monitoring and evaluation plans to conserve mangrove species in Sri Lanka since human interference of canopy eradication for the requirement of wood for extended time period may have devastating impact on natural regeneration pattern of mangrove species.

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