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Research Article

Terebralia palustris Distribution and its Carbon Sequestration in the Mangrove Environment of Port Blair Coastal Stretch, Andaman Islands, India

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Abstract

The faunal and floral species have different eco-services, one of which is carbon sequestration. The loss of such species has a significant impact on environment concern. Under this concept, this work is an attempt to understand the carbon accumulation through *Terebralia palustris* in the selected mangrove environments of Andaman Islands. Three mangrove sites located in and around Port Blair coastal regions was selected i.e. Carbyns Cove Creek, Chidiyatapu and Wandoor. The species *Terebralia palustris* was collected and their flesh and shell was estimated for biometric, organic carbon and carbonate content by the Loss on Ignition and acid titration methods.

The randomly collected specimens length and width in the studied period, suggested that the Carbyns Cove creek station represented almost similar. The station Chidiyatapu and Wandoor suggested an opposite trend, longer the length of Wandoor species and width of Chidiyatapu.The organic carbon content consists of 20.62% to 41.66% in flesh and 2.79 to 4.23% in the shell concentration. The organic carbon variation attributed to spawning activities and carbonate variation suggested that there might be an impact on the mangrove species such as *Rhizophora* species and *Avicennia marina* species. The estimated carbon in the *Terebralia palustris* from Carbyns Cove creek per m^2 was 102.7g C/m^2, the Chidiyatapu sample shows 66g C/m^2 and the Wandoor station exhibited 26.22g C/m^2.

Keywords: Andaman islands; Gastropoda; Mangrove environment India; *Terebralia palustris*

Introduction

Specific characteristic plants i.e. salt-tolerant trees or halophytes, which exist as distinct mono-specific zones along the tropical coastlines [1] characterize mangrove ecosystem. The mangrove occurrence in a wide range of geo-morphological settings i.e. from the estuarine mangrove forests of Southeast Asia to isolated cays that have developed atop carbonate sands and coral rubble along the coasts of the Caribbean, Micronesia, and the Andaman Islands [2]. This environment considered as the most productive and biologically important ecosystems of the world because of their unique ecosystem goods and services to human society as well as coastal and marine systems [3]. Mangrove ecosystems provide important nutrients and organic carbon to the tropical coastal oceans [4-5].

The Mollusca is one of the most well represented taxon of marine origin in the mangrove forests [6-7]. The available mollusc data showed that the mangrove environment represented high density and biomass of mollusc, which is converting primary carbon into animal tissue [8]. Divided the molluscs living in mangroves as native molluscs (*Cerithidea cingulata, Terebralia palustris and Nerita planospira*), facultative molluscs (*Littoraria scabra* and *Crassostrea cucullata*) and migrant molluscs (*Nerita undata* and *Clypeomorus moniliferus*). Similarly, number of gastropod genus (*Ellobium*) and species (*Littoraria scabra, Terebralia palustris*) seem to occur exclusively in mangrove systems.

The most common form of the molluscan fauna of mangrove forests exhibited in the Indo-West Pacific area is Family Potamididae. These snails play important role in mangrove ecosystem. These members are very abundant and easily found on the trunks and roots of mangroves along with the substrate beneath the trees [9]. Further, this group of snail also serve as a bio-indicator of health and ecological changes in the mangrove ecosystem [10].

and act as bio-filters in wastewater [11]. Some Potamidids are also used as a source of food for human consumption. the genus *Terebralia* has large prosobranch, which are frequently observed in larger numbers on the surface of muddy substrate of mangrove forests. *Terebralia palustris* Linnaeus, 1767, the giant mangrove whelk, has been considered as prominent component of mangrove ecosystem in the Indo-West-Pacific region the distribution extended mainly in tropical to subtropical region, that also in mangrove habitats of the Indo-West-Pacific region, from eastern Africa to north Western Australia [12-14]. Among the mangrove prosobranch gastropod, the species *Terebralia palustris* is the largest in size and the maximum length of 12 cm was recorded from South Africa [15,16]. It is equipped with pointed spire with thick, conical and heavy shell. It contains whorls with strong axial ribs crossed by deeply incised spiral grooves. The shell is dark brown in colour, while the flesh has varied shades of green. This species is highly salt tolerant and active in both low and high tides [17,18]. The anatomical differences in the structure of the radula of *Terebralia palustris*, the large shell length (about 5 to 13 cm) animal feed actively on fallen mangrove leaves whilst the young ones (shell length ≤ 5 cm) feed detritus and are active as detritivorous [19-21]. The feeding was observed at both low and high tides, diurnal and nocturnal, but being most active at diurnal low tides.

The prominent epifaunal species *Terebralia palustris* plays a key role for displacing sediment and thereby promoting bioturbation [22]. This species grazes on the sediment, mangrove litter, leaf, stipule, calyx, fruit and propagule reported that a single *Terebralia palustris* can consume 0.8 leaves per day. Commonly, it was observed that clusters of snails feed on a single fallen leaf, often close to similar leaves that remain untouched the primary source of carbon for coastal and estuarine gastropods is acquired from their diets, which mainly are phytoplankton, microalgae or seaweeds and detritus on the intertidal mudflats [23]. Reported that, based on their total carbon percentage available in the soft tissue and shells, the gastropods are the storehouse of carbon. A report from Global and Planetary Change 18 stated that *Terebralia palustris* is one of the gastropods with high calcium carbonate levels in the shell and through the food chain, the organic carbon matter is forwarded through the carbon cycle. The occurrence of carbonate is beneficial in reducing the concentration of free carbon in the atmosphere. Thus, mangrove fauna play a very crucial role in the carbon cycle of the mangroves. The distribution of *Terebralia palustris* is affected by the destruction of mangroves as it is the habitat and food resource for these mangrove whelks. Damage to mangrove forests will cause the death of large numbers of *Terebralia palustris* which acts as blue carbon reservoirs thereby decreasing the contribution to carbon sequestration. Andaman and Nicobar Islands are the largest archipelago, which comprises of more than 572 scattered islands, islets and rocky outcrops. However, in India, that also in Andaman mangrove region, no study was carried out to know the status of *Terebralia palustris* and its carbon accumulation status. This work is an attempt to understand the carbon accumulation through *Terebralia palustris* in the selected mangrove environments of Andaman Islands.

Materials and Methodology

Study Area

The present study covers the muddy intertidal regions of Port Blair coast, which shows rich density of *Terebralia palustris*. The study locations were selected based on the faunal abundance, accessibility for sampling and exposure of the intertidal region during the low tide. The study area consists of 3 stations viz. Carbyns Cove Creek, Chidhiyatapu and Wandoor (Figure 1).

Name of Station	Latitude	Longitude
Carbyns Cove Creek	11°38′19.56″N	92°44′50.32″E
Chidhiyatapu	11°38′19.51″N	92°44′50.22″E
Wandoor	11°35′16.38″N	92°37′02.61″E

Table 1: Study area with station locations

Carbyns Cove Creek (CC)

It is the southern end of the Carbyns Cove beach, where a narrow creek flows to the sea in eastward direction. The banks of this region have muddy substratum and mainly consists of the mangrove tree *Rhizophora mucronata*. The southern side of the bank, mudskippers and fiddler crabs are commonly visible in this region, along with the dominant gastropod *Terebralia palustris*. However, the northern bank is scarcely observed the same. Common human activities in this location included traditional fishing, transportation of building construction materials to the different islands, boat construction and repair.

Chidiyatapu (CT)

This location is situated near the Chidiyatapu beach, i.e. at least three km from the beach. The mangrove patches leads up to Badabalu beach. The substratum is small rocks and pebbles mixed with mud. The region has mangrove trees like *Rhizophora mucronata* and *Avicennia marina.* Faunal diversity mostly consists of mangrove snakes, mudskippers, juvenile fishes and crabs, hermit crabs, gastropods like *Littorina, Nerita* and *Terebralia palustris.* Fishing by the use of cast net was commonly sighted as human activity during the sample collection.

Wandoor (WA)

This location is situated before reaching to the Wandoor beach. It consists of back mangroves mainly marsh grasses with very scanty growth of *Avicennia marina.* The substratum is rocky

and muddy. This location has a variety of crabs and giant mangrove whelks (*Terebralia palustris*) as the dominant gastropod.

Sampling Schedule

The sampling for the present study was carried out during the low tides from December 2018 and February 2019. Samples were collected from each of the 3 stations in two quadrates. A total of 112 individual specimens of *Terebralia palustris* were collected during the study.

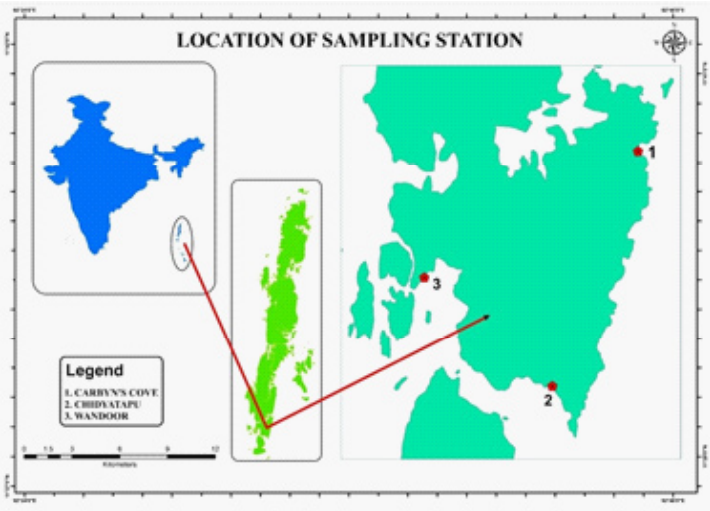

Figure 1: Study Area Map.

Method of Analysis

The sampling was done for two months during low tides in each of the 3 stations. At a single station, 2 random quadrates, per month were taken. All the locations, the species *Terebralia palustris* was found aggregated near the mangrove roots. The number of whelks in each quadrat was counted and noted to estimate the density variation of the specimen in these 3 stations. 10 whelks were collected from each quadrat for biometric analysis. The length and width of the whelks were measured using linear scale (cm). The total weights of the whelks were measured using electrical weighing machine (g). Out of these 10 samples, five individuals were selected for carbon and carbonate content analysis. The shell and the flesh of these 5 whelks, from each quadrat were separated. The shells were broken by hammering and the flesh attached to the shell was removed by the help of forceps. With the help of electrical weighing machine, the weights of the flesh in wet and dry was measured individually along with that the shell weight were noted separately.

The flesh and shells were put in petri dishes separately and were kept inside the Hot Air Oven at 40˚C for 24 hours. The large shells were broken with hammer prior to keeping in oven for easy drying. After complete drying, the samples were taken out of the oven carefully. The samples were then broken into small pieces with the help of hammer and then further grinded in mortar and pestle to get fine homogenous powder for carbon and carbonate content analysis. Care was taken to keep the samples without any contamination, among the samples as well as other outside activities. The carbon content was estimated by Loss on Ignition method through Muffle Furnace with pre-weighed porcelain crucible, at 400˚C and one hour time period. The weight loss was converted in to percentage as well as in mg scale for different calculation. The carbonate content was estimated by the NaOH titration method against the HCl. The dissolution of 1.25 gram of each flesh and shell powder was made with known concentration of HCl and then the acid consumption was estimated for the equivalence of carbonate and converted in to percentage. Different statistical treatment such as mean, standard deviation and graphical representation for this data was carried out using the excel programme. The estimation of carbon sequestration by the species *Terebralia palustris* for $1m^2$ was also calculated. These results were attributed and discussed for their impacts in these environments.

Results and Discussion

Terebralia palustris species was studied in the three different mangrove environments situated in and around Port Blair. The study represented Carbyns Cove creek has the highest number of species recorded than the other two stations viz., Chidiyatapu and Wandoor. The Carbyns Cove creek station represented highest population of *Terebralia palustris* i.e. 96 individuals per m^2. Among the two studied quadrates of this location (Table 1). One sample constantly represented 96 individuals per m^2 and the other samples represented 51 to 83 individuals per m^2.

	Carbyns Cove creek In Numbers	Chidiyatapu In Numbers	Wandoor In Numbers
	December 2018		
Te-Q1	96	87	39
Te-Q2	83	65	36
Mean	**90**	**76**	**38**
	February -2019		
Te-Q1	96	67	68
Te-Q2	51	45	39
Mean	**74**	**56**	**54**

Table 1: *Terebralia palustris (*Te) population in quadrates of study period. (Q1, Q2) - Quadrates.

The station Chidiyatapu represented 67 to 87 individuals per m^2 in the study period in one sample and in the other sample, it was 45 to 65 individuals per m^2. The station Wandoor represented 39 to 68 individuals per m^2 and 36 to 39 individuals per m^2 for the other stations. The study was conducted in the month of December 2018 and February 2019. Among these periods, during the month of December, 2018 it was observed more number of individuals present than the month of February, 2019 for the locations Carbyns Cove creek (December- 96 and 83; February- 96 and 51 individuals) and Chidiyatapu (December- 87 and 65; February- 67 and 45 individuals). However, the station Wandoor represented vice-versa status of availabilities of individuals among the study period (December-39 and 36; February- 68 and 39 individuals). The randomly collected specimens from the quadrates in Carbyns Cove creek varied its length from 2.1 to 8.8 cm and width varied from 0.8 to 3.8 cm during the month of December 2018 and 2.6 to 8.4 cm length and 1 to 3.1 cm width of individuals was observed during the month of February 2019. The total weight (shell with flesh) of the individuals varied from 1.229g to 48.617g during the month of December and flesh weight varied between 0.085g to 6.032g (Table 2). During the month February 2019 it was found that the total weight varied between 1.607g to 28.220g and the flesh weight varied from 0.090g to 5.234g.

December 2018	Standard Length SL (cm)	Standard Width SW (cm)	Total Weight (g)	Flesh Weight (g)	Shell Weight (g)
	2.9	1.2	1.844	0.216	1.628
	2.8	1.0	1.597	0.202	1.395
	2.6	1.2	1.844	0.216	1.628
	2.8	1.4	1.825	0.276	1.549
	2.1	0.8	1.631	0.225	1.406
	7.4	2.7	25.078	4.378	20.7
	7.2	2.8	25.098	5.168	19.93
	7.1	2.4	18.781	2.744	16.037
	8.8	3.7	48.617	5.530	43.087
	7.0	2.6	18.091	2.695	15.396
	8.0	3.8	45.213	4.87	40.343
	7.5	2.6	28.011	6.032	21.979
	2.2	1.0	1.890	0.238	1.652
	2.5	1.2	1.639	0.341	1.298

	2.8	1.3	1.602	0.212	1.390
	2.9	1.0	1.539	0.133	1.406
	3.0	1.1	1.619	0.085	1.534
	2.3	0.9	1.288	0.141	1.147
	2.2	0.8	1.229	0.132	1.097
	2.3	1.0	1.382	0.13	1.252
	7.4	2.5	18.081	1.204	16.877
	8.1	2.2	26.51	2.561	23.949
	7.9	2.8	28.502	3.008	25.494
	6.2	2.5	19.918	2.001	17.917
	8.4	3.0	28.214	2.706	25.508
MEAN	**4.98**	**1.9**	**14.04**	**1.82**	**12.22**
S.D.	**2.61**	**0.95**	**14.82**	**2.02**	**13.00**
February 2019	**Standard Length SL (cm)**	**Standard Width SW (cm)**	**Total Weight (g)**	**Flesh Weight (g)**	**Shell Weight (g)**
	3.2	1.2	2.394	0.299	2.095
	3.0	1.2	1.613	0.258	1.355
	2.6	1.0	1.607	0.172	1.435
	5.0	1.2	6.504	0.993	5.511
	5.8	1.8	10.374	1.902	8.472
	7.0	2.5	18.499	3.354	15.145
	8.2	3.0	28.106	4.662	23.444
	4.2	1.6	5.854	0.829	5.025
	8.1	2.5	28.032	5.234	22.798
	5.2	1.3	7.109	0.255	6.854
	2.7	1.7	1.873	0.200	1.673
	2.8	1.2	1.899	0.257	1.642
	6.0	2.2	15.069	2.686	12.383
	6.5	2.0	14.543	2.223	12.32
	7.0	2.5	20.119	3.495	16.624
	7.2	2.6	20.556	4.008	16.548
	8.1	2.2	26.500	2.600	23.900

	6.2	2.4	19.92	2.300	17.62
	3.0	1.0	1.702	0.090	1.612
	8.4	3.1	28.22	2.71	25.51
MEAN	**5.51**	**1.91**	**13.03**	**1.93**	**11.10**
S.D.	**2.07**	**0.68**	**10.11**	**1.65**	**8.63**

Table 2: Carbyns Cove creek samples meristic details for the species *Terebralia palustris*.

The station Chidiyatapu represented the species *Terebralia palustris* in the length of 4.7 to 6.9 cm and 1.9 to 2.6 cm width during the month of December 2018 (Table 3). The total weight varied between 7.234g to 22.013g and flesh weight varied between 0.392g to 1.108g. However, during the month of February, 2019 the length of the specimen varied from 3.2 to 12.2 cm and width varied from 1.1 to 5.3 cm. The total weight varied from 2.216g to 94.535g and flesh weight showed the range of 0.216g to 10.412g.

December 2018	**Standard Length SL (cm)**	**Standard Width SW (cm)**	**Total Weight (g)**	**Flesh Weight (g)**	**Shell Weight (g)**
	4.8	1.9	8.797	0.392	8.405
	5.6	2.3	11.305	0.489	10.816
	5.4	2.0	9.970	0.551	9.419
	5.5	2.4	11.461	0.660	10.801
	6.9	2.6	21.929	0.910	21.019
	6.0	2.5	14.826	1.108	13.718
	5.2	2.0	7.234	0.498	6.736
	4.7	2.1	8.081	0.402	7.679
	6.9	2.5	22.013	1.102	20.911
MEAN	**5.67**	**2.26**	**12.85**	**0.68**	**12.17**
S.D.	**0.80**	**0.26**	**5.63**	**0.29**	**5.39**
February 2019	**Standard Length SL (cm)**	**Standard Width SW (cm)**	**Total Weight (g)**	**Flesh Weight (g)**	**Shell Weight (g)**
	3.2	1.1	2.216	0.216	2.000
	3.4	1.6	3.837	0.479	3.358
	3.9	1.5	5.073	0.616	4.457
	5.1	2.0	10.03	1.161	8.869
	6.5	2.5	16.651	2.569	14.082
	4.7	2.0	8.981	0.329	8.652
	6.8	3.2	20.932	0.896	20.036
	5.2	2.9	9.235	1.078	8.157
	5.6	2.4	11.209	0.500	10.709
	7.0	2.8	21.93	0.909	21.021
	7.6	2.8	24.235	3.812	20.423

	7.0	2.7	21.717	2.921	18.796
	8.2	3.2	30.757	5.34	25.417
	9.0	3.4	50.661	5.995	44.666
	8.2	3.6	41.192	3.056	38.136
	12.2	5.3	94.535	10.412	84.123
	9.6	3.5	47.628	4.127	43.501
	8.5	3.2	35.144	4.408	30.736
MEAN	**6.76**	**2.77**	**25.33**	**2.71**	**22.62**
S.D.	**2.35**	**0.96**	**22.74**	**2.67**	**20.66**

Table 3: Chidiyatapu samples meristic details for the species *Terebralia palustris*.

The individual specimen morphometric details suggested that the Wandoor station exhibited *Terebralia palustris* with the length of 3.4 to 7.7 cm and 1.1 to 2.5 cm width during the month of December 2018 (Table 4). The total weight varied between 2.93g to 20.864g with the flesh weight of 0.424g to 4.419g. During the month of February 2019, the length varied from 3.8 to 7.8 cm and width 1.5 to 3.2 cm. The total weight varied from 3.933g to 21.08g and flesh weight varied between 0.582g to 4.519g.

December 2018	Standard Length SL (cm)	Standard Width SW (cm)	Total Weight (g)	Flesh Weight (g)	Shell Weight (g)
	3.4	1.8	2.930	0.424	2.506
	4.5	1.8	6.407	1.226	5.181
	3.9	1.9	4.367	0.518	3.849
	4.7	2.0	8.021	1.622	6.399
	5.4	2.2	11.19	1.889	9.301
	5.8	2.2	12.722	2.228	10.494
	4.4	1.7	6.121	1.198	4.923
	5.2	2.3	10.074	2.519	7.555
	4.4	1.6	5.565	0.84	4.725
	6.5	2.5	17.861	3.84	14.021
	4.3	1.6	4.819	0.916	3.903
	4.1	1.1	5.184	1.026	4.158
	4.2	1.8	5.548	0.866	4.682
	4.2	1.6	4.816	0.992	3.824
	4.6	1.8	6.025	1.352	4.673
	5.8	2.2	11.861	2.844	9.017
	5.0	1.9	8.478	1.565	6.913
	6.0	2.3	13.353	2.872	10.481
	7.7	2.3	20.864	4.419	16.445

	4.8	1.7	6.600	1.296	5.304
MEAN	**4.95**	**1.92**	**8.64**	**1.72**	**6.92**
S.D.	**1.02**	**0.34**	**4.74**	**1.09**	**3.68**
February 2019	**Standard Length SL (cm)**	**Standard Width SW (cm)**	**Total Weight (g)**	**Flesh Weight (g)**	**Shell Weight (g)**
	4.0	1.5	3.933	0.582	3.351
	4.0	1.6	4.336	0.584	3.752
	4.4	1.7	5.292	0.978	4.314
	4.6	2.0	6.583	1.152	5.431
	5.6	2.0	13.002	1.804	11.198
	5.4	2.1	11.200	1.899	9.301
	5.2	2.4	10.063	2.520	7.543
	3.8	1.8	4.876	0.620	4.256
	6.6	2.7	18.012	3.845	14.167
	4.5	1.7	5.301	0.960	4.341
	5.4	2.1	11.883	1.542	10.341
	5.5	2.0	10.499	1.584	8.915
	5.7	2.2	11.357	2.147	9.210
	6.2	2.4	15.243	2.746	12.497
	7.1	2.2	21.08	2.888	18.192
	6.2	3.2	13.079	2.001	11.078
	7.8	2.3	20.641	4.519	16.122
	5.7	2.2	10.789	2.211	8.578
	5.0	1.7	7.700	1.248	6.452
	5.8	2.2	11.863	2.794	9.069
MEAN	**5.43**	**2.1**	**10.84**	**1.93**	**8.91**
S.D.	**1.05**	**0.4**	**5.13**	**1.07**	**4.18**

Table 4: Wandoor samples meristic details for the species *Terebralia palustris*.

The organic carbon analysis result represented that for Carbyns Cove creek the percentage of organic carbon in the flesh of *Terebralia palustris* varied from 7.75% to 73.09% and varied in the shells from 2.80% to 6.29% for the month of December 2018 (Table 5). The organic carbon percentage of the individuals in the flesh observed from 14.06% to 79.23% and the range was 2.72% to 5.03% in the shells for the month of February 2019 (Table 6).

December 2018	Flesh Weight (g)	Organic Carbon-%-Flesh	Carbonate -%- Flesh	Shell Weight (g)	Organic Carbon-%-Shell	Carbonate -%- Shell
CC/TE/Q1/1	0.22	23.21	1.00	01.63	3.28	74.00
CC/TE/Q1/2	0.20	21.88	0.50	01.40	3.43	52.00
CC/TE/Q1/4	0.28	60.00	0.75	01.55	2.80	59.00
CC/TE/Q1/7	5.17	71.99	2.00	19.93	5.04	100.00
CC/TE/Q1/10	2.70	71.43	3.00	15.40	3.96	100.00
CC/TE/Q2/1	0.13	21.61	0.25	01.41	6.30	40.00
CC/TE/Q2/3	0.14	20.00	0.25	01.15	3.78	35.00
CC/TE/Q2/4	0.13	14.29	0.25	01.10	3.83	36.00
CC/TE/Q2/5	0.13	07.75	0.25	01.25	5.68	40.00
CC/TE/Q2/7	2.56	73.09	0.25	23.95	4.23	100.00
MEAN	**1.17**	**38.52**	**0.85**	**6.87**	**4.23**	**63.60**
S.D.	**1.74**	**26.94**	**0.94**	**9.12**	**1.11**	**27.75**

Table 5: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Carbyns Cove creek, during the month of December 2018.

February 2019	Flesh Weight (g)	Organic Carbon-%-Flesh	Carbonate -%- Flesh	Shell Weight (g)	Organic Carbon-%-Shell	Carbonate -%- Shell
CC/TE/Q1/1	0.30	16.30	1.00	02.10	4.38	82.00
CC/TE/Q1/3	0.17	21.61	0.75	01.43	5.03	34.00
CC/TE/Q1/4	0.99	14.52	1.50	05.51	2.92	100.00
CC/TE/Q1/5	1.90	73.80	0.75	08.47	2.96	98.00
CC/TE/Q1/8	4.66	18.97	1.00	23.44	2.72	94.00
CC/TE/Q2/1	0.20	14.06	0.50	01.67	4.71	66.00
CC/TE/Q2/2	0.26	23.00	0.50	01.64	4.38	62.00
CC/TE/Q2/3	2.69	70.30	2.00	12.38	2.84	100.00
CC/TE/Q2/4	2.22	18.96	1.80	12.32	3.71	100.00
CC/TE/Q2/5	3.50	79.23	10.00	16.62	4.80	88.00
MEAN	**1.69**	**35.08**	**1.98**	**18.69**	**3.85**	**82.40**
S.D.	**1.58**	**27.39**	**2.87**	**8.19**	**0.92**	**22.03**

Table 6: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Carbyns Cove creek, during the month of February 2019.

The station Chidiyatapu exhibited the organic carbon percentage in the individuals varied from 23.78% to 88.24% in the flesh and 3.94% to 5.71% in the shells for the month of December 2018 (Table 7). The percentage of organic carbon in the flesh varied from 14.70% to 70.77% and in the shells 3.59% to 4.80% for the month of February 2019 (Table 8).

December 2018	Flesh Weight (g)	Organic Carbon-%-Flesh	Carbonate -%- Flesh	Shell Weight (g)	Organic Carbon-%-Shell	Carbonate -%- Shell
CT/TE/Q1/1	0.39	86.49	0.50	08.41	4.84	21.00
CT/TE/Q1/3	0.49	88.24	0.50	10.82	4.00	55.00
CT/TE/Q1/4	0.55	24.50	0.50	09.42	4.01	86.00
CT/TE/Q1/5	0.66	23.80	0.50	10.80	5.71	100.00
CT/TE/Q1/6	0.91	23.78	0.50	21.02	3.94	100.00
MEAN	**0.60**	**49.36**	**0.50**	**12.09**	**4.50**	**72.40**
S.D.	**0.20**	**34.70**	**0.00**	**05.09**	**0.77**	**34.11**

Table 7: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Chidiyatapu, during the month of December 2018.

February 2019	Flesh Weight (g)	Organic Carbon-%-Flesh	Carbonate -%- Flesh	Shell Weight (g)	Organic Carbon-%-Shell	Carbonate -%- Shell
CT/TE/Q1/1	0.21	20.31	0.50	2.00	4.80	48.00
CT/TE/Q1/2	0.48	19.20	0.50	3.36	4.40	49.00
CT/TE/Q1/3	0.62	14.70	1.50	4.46	3.59	40.00
CT/TE/Q1/4	1.16	20.57	0.50	8. 87	4.51	36.00
CT/TE/Q1/5	2.57	50.10	0.75	14.08	4.06	88.00
CT/TE/Q2/1	3.81	63.27	8.00	20.42	4.57	96.00
CT/TE/Q2/2	2.92	70.77	0.75	18.80	3.91	89.00
CT/TE/Q2/3	5.34	67.07	10.00	25.42	4.38	91.00
CT/TE/Q2/4	6.00	48.97	10.00	44.67	4.08	100.00
MEAN	**2.57**	**41.66**	**3.61**	**15.79**	**4.26**	**70.78**
S.D.	**2.14**	**22.96**	**4.34**	**13.61**	**0.37**	**26.64**

Table 8: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Chidiyatapu, during the month of February 2019.

The station Wandoor represented the percentage of organic carbon in the flesh between 9.58% to 43.49% and 2.37% to 3.50% for the month of December 2018 (Table 9). The organic carbon percentage varied from 12.91% to 26.34% in flesh and 2.71% to 4.50% in shells for the month of February 2019 (Table 10).

December 2018	Flesh Weight (g)	Organic Carbon-%-Flesh	Carbonate -%- Flesh	Shell Weight (g)	Organic Carbon-%-Shell	Carbonate -%- Shell
WN/TE/Q1/1	0.42	09.87	0.50	2.51	3.50	100.00
WN/TE/Q1/3	0.52	20.40	0.50	3.85	3.14	98.00
WN/TE/Q1/5	1.89	43.48	0.50	9.30	2.57	100.00
WN/TE/Q1/7	1.20	11.04	0.75	4.92	2.43	100.00
WN/TE/Q1/9	0.84	12.12	1.00	4.73	2.37	100.00

WN/TE/Q2/2	1.03	12.43	0.50	4.16	2.77	96.00
WN/TE/Q2/4	0.99	10.90	0.50	3.82	3.20	98.00
WN/TE/Q2/6	2.84	42.44	3.00	9.02	2.53	96.00
WN/TE/Q2/8	2.87	38.74	1.00	10.48	2.49	95.00
WN/TE/Q2/10	1.30	09.58	0.50	5.30	2.91	94.00
Mean	**1.39**	**21.10**	**0.88**	**5.81**	**2.79**	**97.70**
S.D	**0.93**	**14.48**	**0.78**	**2.75**	**0.38**	**2.31**

Table 9: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Wandoor during the month of December 2018.

February 2019	**Flesh Weight (g)**	**Organic Carbon-%-Flesh**	**Carbonate-%- Flesh**	**Shell Weight (g)**	**Organic Carbon-%-Shell**	**Carbonate -%- Shell**
WN/TE/Q1/1	0.58	21.43	0.50	3.36	3.30	74.00
WN/TE/Q1/2	0.58	23.19	0.50	3.75	3.13	74.00
WN/TE/Q1/3	0.98	22.14	0.25	4.31	2.71	82.00
WN/TE/Q1/4	1.15	26.34	0.50	5.43	3.67	67.00
WN/TE/Q1/5	1.80	24.43	0.25	11.20	4.50	68.00
WN/TE/Q2/1	1.54	22.44	0.50	10.34	4.29	49.00
WN/TE/Q2/2	1.58	16.74	1.00	8.92	3.39	66.00
WN/TE/Q2/3	2.15	12.91	0.25	9.21	3.62	53.00
WN/TE/Q2/4	2.75	17.21	0.25	12.50	2.95	60.00
WN/TE/Q2/5	2.89	19.41	0.25	18.19	2.88	87.00
MEAN	**1.60**	**20.62**	**0.43**	**8.72**	**3.44**	**68.00**
S.D.	**0.81**	**4.05**	**0.24**	**4.68**	**0.59**	**11.94**

Table 10: Estimated Organic Carbon and Carbonate content of random samples of *Terebralia palustris* from Wandoor during the month of February 2019.

The samples collected during the month of December 2018, from the Wandoor station, represented 0.5% to 3% of carbonate in the flesh and 94% to 100% of carbonate in the shells. However, the samples collected during the month of February 2019 represented 0.25% to 1% carbonate in the flesh and 49% to 87% of carbonate in the shells(Tables 9 and 10). The species *Terebralia palustris* presence in the stations suggested that during the month of December, 2018 and February, 2019 Carbyns Cove creek (82 nos.) represented highest mean number of individuals than Chidiyatapu (66 nos.) and Wandoor (46 nos.). This variation may be suggested that Carbyns Cove creek environment may have good niche for this species than Chidiyatapu and Wandoor(Figure 2). Further it was identified the whole environment of Carbyns Cove creek represented by *Rhizophora mucronata*species. However, in the case of Chidiyatappu, it was mixed with *Rhizophora mucronata*and *Avicennia marina* species and Wandoor shows exclusively *Avicennia marina* species. The study of reported in Kenyan waters a different kind of population structure with reference to the *Rhizophora mucronata* and *Avicennia marina* mangrove species. also reported that the location Mida which has good amount of *Avicennia marina* exhibited comparatively higher population of *Terebralia palustris* than the station Dabaso which is dominated by *Rhizophora mucronata.* Further, also reported that the variation among the stations due to abiotic parameters of these locations. Present study shows that the abiotic parameters are similar in nature, so the present variation may be inferred to influence of mangrove species differences reported that the *Avicennia marina* environment has low level of food resources than *Rhizophora species.*For the developmental activities of *Terebralia palustris*[24]. Reported that the species *Terebralia palustris* identified in rich *Rhizophora mucronata*location than the devoid of this species. This information

has also support mangrove species influence on the population of *Terebralia palustris*[25]. Reported that *Terebralia palustris*located in the *Rhizophora mucronata* enriched mangrove environments of Michamvi Zanzibar, Tanzania.

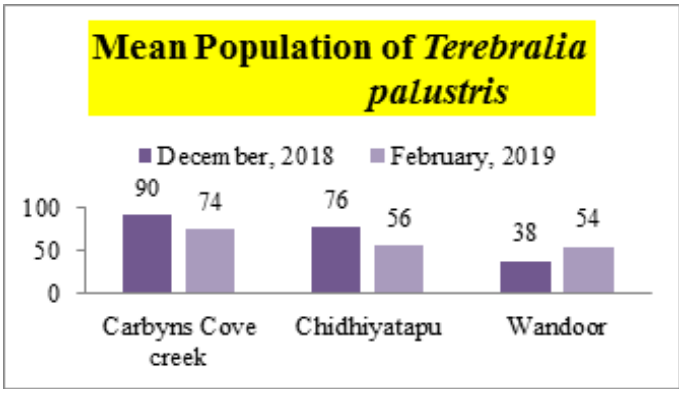

Figure 2: Distribution of *Terebralia palustris* in the study area.

Another interesting fact was observed in the stations Carbyns Cove creek (December - 90 nos.; February - 74 nos.) and Chidiyatapu (December - 76 nos.; February - 56 nos.) that during the month of December 2018 exhibited more number of individuals (Figure 3) for *Terebralia palustris* than February, 2019 collection. However, the Wandoor station (December - 38 nos.; February - 54 nos.) showed a vice versa character for this species distribution.

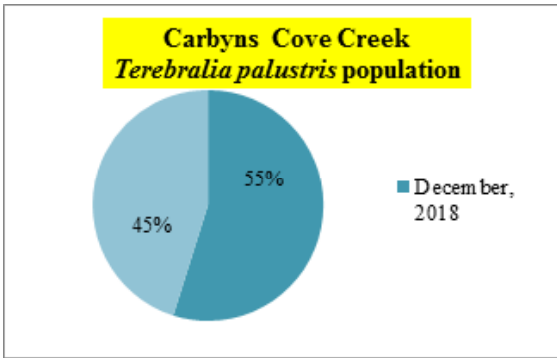

Figure 3: Distribution of *Terebralia palustris* in the Station Carbyns Cove Creek.

The randomly collected specimens studied for meristic characters suggested that the Carbyns Cove creek station represented almost similar length and width in the studied period (length 4.98-5.51 cm; width 1.9-1.91 cm). However, the total weight (TW) of shell and flesh and exclusively flesh weight (FW) suggested that it was lower in February 2019 (TW- 13.03g; FW- 1.93g) than the month of December 2018 (TW- 14.04g; FW- 1.82g). The station Chidiyatapu and Wandoor (Figures 4,5) suggested an opposite trend than the Carbyns Cove creek station. The length and width of Chidiyatapu (CT) and Wandoor (WA) stations suggested an increment during the month of February, 2019 (CT- length- 6.76 cm; width 2.77cm; WA- length-5.43 cm; width 2.10 cm) than the month of December, 2018 (CT- length- 5.67 cm; width 2.26 cm; WA- length- 4.95 cm; width 1.92 cm).

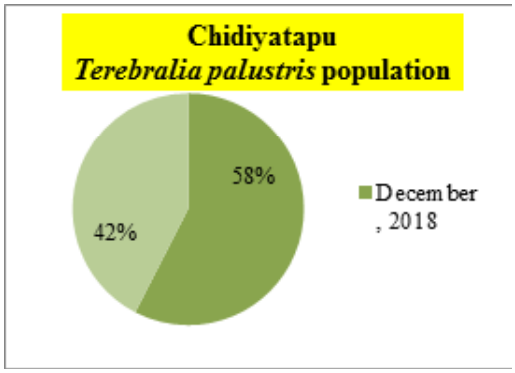

Figure 4: Distribution of *Terebralia palustris* in the Station Chidiyatapu.

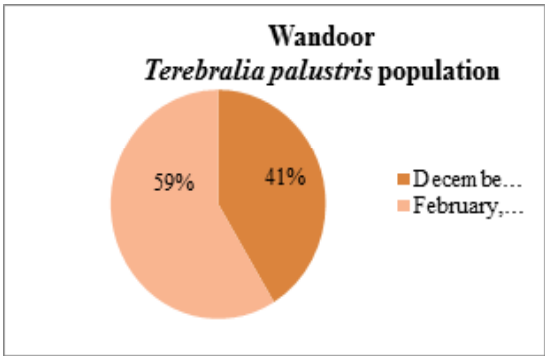

Figure 5: Distribution of *Terebralia palustris* in the Station Wandoor.

This variation of meristic characters may be suggested that differences of spawning activities may be taken place between the stations Carbyns Cove creek, Chidiyatapu and Wandoor. The stations Chidiyatapu and Wandoor variation may be due to the maturity stages of *Terebralia palustris,* i.e., December 2018 it may be comparatively juvenile and it was grown during the month of February 2019 reported that in Mida creek of Kenya showed 0.5 cm to 13.0 cm length of *Terebralia palustris.* The present study reported 1.1 cm to 12.2 cm length of *Terebralia palustris* minimum and maximum length. However, the mean length of 4.98 cm to 5.51 cm in Carbyns Cove creek, 5.67 cm to 6.76 cm length of *Terebralia palustris* in Chidiyatapu and 4.95 cm to 5.43 cm length in Wandoor samples of *Terebralia palustris* suggested that just those species attained the maturity from the juveniles to adults (Figures 6-8). Reports the immature to matured stage varied between 5 cm to 6 cm length of the *Terebralia palustris* in their study locations. This information also supported Carbyns Cove creek samples at-

tained the maturity at 6 cm size class and in the case of Chidiyatapu and Wandoor it may be of 5 cm. This information has been suggested the reason for the differences of weight was inferred from these study locations [26]. Reported that the South African locations Durban Bay and Kosi Bay respectively showed the maximum length of 6.0 cm and 3.18 cm for the species *Terebralia palustris*. However, the present study species average length varied between 4.98 to 5.51 cm for Carbyns Cove creek and 5.67 to 6.76 cm for Chidiyatapu and 4.95 to 5.43 cm for Wandoor. This length of present study almost matched with the South African waters species growth.

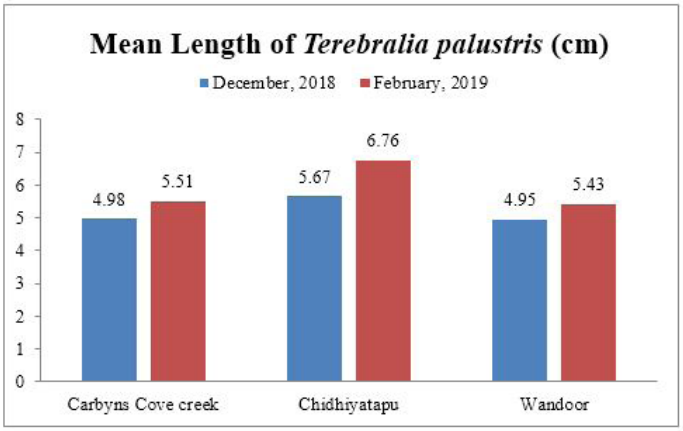

Figure 6: Distribution of *Terebralia palustris* Mean Length in the Studied Locations.

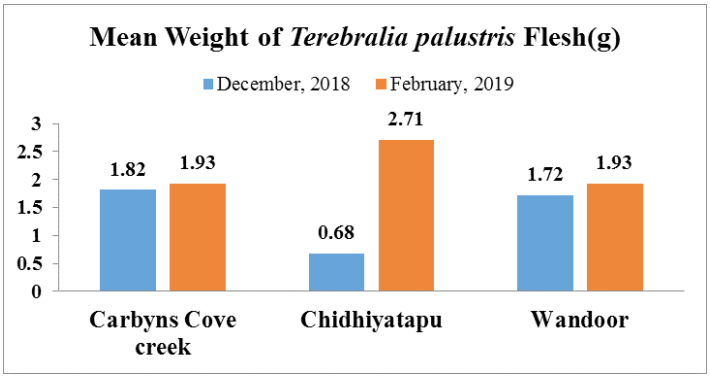

Figure 7: Distribution of *Terebralia palustris* Mean Weight in the Studied Locations.

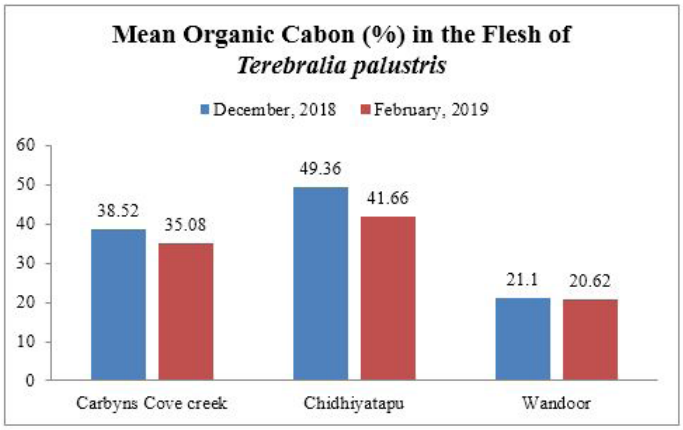

Figure 8: Distribution of *Terebralia palustris* Mean Organic Carbon in the Flesh, in the Studied Locations.

The organic carbon observed in the flesh represented 38.52% and 35.08%, respectively, December 2018 and February 2019 study period in Carbyns Cove creek samples. The shells exhibited 4.23% and 3.85% mean value of December 2018 and February, 2019 samples. The station Chidiyatapu exhibited the *Terebralia palustris* flesh have the carbon content of 49.36% and 41.66%, respectively, December, 2018 and February, 2019 study period. The respective shells were estimated for their carbon content suggested 4.50% and 4.26% respectively, December 2018 and February 2019.

The station Wandoor samples of *Terebralia palustris* flesh content exhibited its organic carbon value in 21.10% and 20.62% respectively in December 2018 and February 2019. The respective shell content organic carbon represented 2.79% and 3.44% during the months of December 2018 and February 2019. The above results clearly support the fact that 50% of the flesh weight consists of Carbon. Over and above, the organic carbon percentage also matched with the meristic characters observed for the species *Terebralia palustris,* i.e. the lower flesh weight during the month of February 2019 than December 2018 in the station Carbyns Cove creek suggested that due to the spawning activities the flesh weight reduced but due to the different biological activities the carbon

content of the flesh show an increment than the month of December, 2018. Similarly, in the case of Chidiyatapu and Wandoor the December 2018 month flesh samples exhibited comparatively higher carbon than the February 2019 samples may be due to the growth of juveniles to adults. This inference was supported by the fact during the juvenile the *Terebralia palustris feed* on detritus and adults feed only mangrove leaves. Reported that the juveniles of *Terebralia palustris* are detriticolous and adults are leaf-litter feeders. This was very much matched with the inferences made on the present study. The shells of all the studied samples not show much differences of concentration (2.79 to 4.23 %) may be due to the availabilities of carbon in the form of carbonates, which are almost similar in concentration. The estimated carbon in the *Terebralia palustris* from Carbyns Cove creek per m^2 was 102.7g C/m^2, the Chidiyatapu sample shows 66g C/m^2 and the wan door station exhibited 26.22g C/m^2 (Table 11). This carbon concentration was lower than Panjang Island species population per m^2 and almost similar to Zegrzynski lake location population per m^2 [27]. However, the study area of Carbyns Cove creek and Chidhiyatapu match with the Zegrzynski lake population but the wan door station was lower than the Zegrzynski lake population.

Average number of individuals in m^2 x Average Carbon in the flesh = Sequestrated Carbon.

	Organic Carbon Sequestration in m^2
Carbyns Cove creek	79x1.30g=102.7g
Chidiyatapu	66x1.00g= 66.0g
Wan door	46x0.57g= 26.22g

Table 11: Estimation of Carbon sequestration by *Terebralia palustris* in m^2 area.

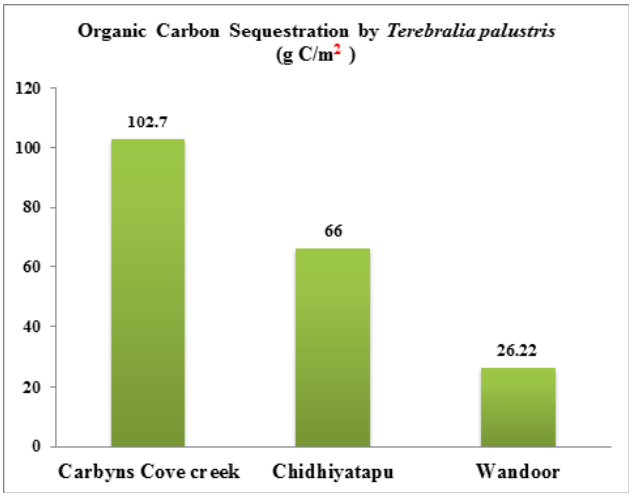

Figure 9: Distribution of Carbon sequestration by *Terebralia palustris* in m^2 area.

The carbonate content availability in the flesh represented in the range of 0.85% to 1.98% and 0.50% to 3.61% in the Carbyns Cove creek and Chidiyatapu station samples, respectively [28]. The Wandoor samples flesh represented 0.88% to 0.43% of carbonate. This result forced to infer that the availability of the *Rhizophora* species might have an influence for this elemental variation, in the stations Carbyns Cove creek and Chidiyatapu where the *Rhizophora* species was identified near the sample collection locations [29]. However, the Wandoor station clearly suggested that devoid of *Rhizophora* species and presence of *Avicennia marina* also support the above inference. The shell content of the studied species show almost equi-level of average carbonate content (60% to 68%) suggested that the species shell composition almost similar in nature. The increment of carbonate content in the shells of Wandoor stations December 2018 samples may be due to the comparatively juvenile species existence during this period.

The estimated carbon in the *Terebralia palustris* from Carbyns Cove creek per $m^2$was 102.7g C/m^2, the Chidiyatapu sample shows 66g C/m^2 and the Wandoor station exhibited 26.22g C/m^2. However, the study area of Carbyns Cove creek and Chidiyatapu match with the Zegrzynski lake population but the wan door station was lower than the Zegrzynski lake population.

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