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Research Article

Dominant gastropods of Indian Sundarbans: A major sink of carbon

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ABSTRACT

The mangrove dominated Indian Sundarbans are rich bed for several species of gastropods. These gastropods are the store house of carbon as evidenced from the concentrations of total carbon (% dry weight) in their soft tissues and shells. The present study reveals significant spatial differences of stored carbon in selected gastropod species in Indian Sundarbans, which might be due to carbon derived from their food like algal mat, litter and detritus of mangroves that is more in the eastern sector of Indian Sundarbans compared to the central and western sectors. The stored carbon also exhibited species-wise variation and the order is *Cerithedia obtusa*> *Nerita articulata*> *Telescopium telescopium*> *Cerithedia cingulata* irrespective of locations.

Keywords: Indian Sundarbans, stored carbon, soft tissues of gastropods, shells of gastropods.

INTRODUCTION

The class Gastropoda (consisting of organisms like snails and slugs) are by far the most numerous molluscs in terms of classified and identified species, and account for 80 percent of the total species. The gastropods mainly depend on algal material and detritus as food sources. These food sources are rich in carbon [1]. Researchers have documented that organic carbon percentage in Indian Sundarbans vary between 0.5-1.9 [2]. The seaweeds are also store houses of carbon. The percentage of carbon content varied from 31.53% to 38.22 % in *Enteromorpha intestinalis*, 27.19% to 31.22% in *Ulva lactuca* and 19.43% to 23.85% in *Catenella repens*[1]. Considering the food habit, population density and biomass of gastropods in the intertidal mudflat of tropical estuaries, it is therefore important to evaluate the potential of gastropod community as sink of carbon. The present manuscript is a snapshot towards this direction. The dominant gastropods in the mangrove dominated Sundarbans are *Telescopium*

telescopium, *Cerithedia obtusa*, *Cerithedia cingulata*, *Nerita articulata*, *Cymia lacera*, *Littorina* spp. *etc.* (Fig. 1). These gastropods are widely distributed in the intertidal mudflats of Indian Sundarbans and they prefer variety of diet. It is thus clear that diet may be one of the primary criteria for inter-specific variation of stored carbon. In this study we have focused on four dominant gastropod species namely *T.telescopium*, *C. obtusa*, *C. cingulata* and *N. articulata* for estimating the stored carbon in their flesh and outermost calcareous shell.

MATERIAL AND METHODS

Sampling:

The entire network of the present study encompasses the three sectors of the Indian Sundarbans viz. western, central and eastern sectors. These three sectors are significantly different from each other with respect to salinity and anthropogenic stress [3, 4]. The western sector is relatively less saline as it receives the discharge from the Farakka Barrage through Bhagirathi-Ganga-Hoogly system and run-off from rivers like Rupnarayan, Haldi *etc*[5]. The central sector is hypersaline in nature due to complete absence of fresh water supply from the upstream region owing to blockage of the Bidyadhari River due to huge siltation. The eastern sector of Indian Sundarbans adjacent to Bangladesh Sundarbans receives fresh water from several channels and creeks from the Padma - Meghna - Brahmaputra river system and their tributaries [4]. The anthropogenic pressure is practically nil in the eastern sector owing to its location in the Reserved Forest zone. Three stations namely Sagar South (21°38′54.37″and 88°03′06.17″), Jharkhali (22°05′52.82″ and 88°41′47.25″) and Chamta (21°53′05.91″N and 88°57′26.52″E) were selected in the western, central and eastern sectors respectively for the present study. Four gastropod species (*T. telescopium*, *C. obtusa*, *C. cingulata* and *N. articulata*) were collected from the inter-tidal mudflats of these stations during low tide condition to estimate the carbon stored in the soft fleshy and hard outer calcareous parts of these species. The study was conducted during April, 2013, which is a premonsoon month, characterized by high salinity and relatively high pH of the aquatic phase.

Analysis of carbon:

The collected gastropods were washed with double distilled water. Soft tissues were separated from shells and both (soft mass and shell) were dried separately to a constant weight and homogenized in an agate mortar. 10-12 samples of the soft tissues and shells from each species were mixed thoroughly by grinding. The concentrations of carbon was determined in subsamples of the soft tissues and shells by means of a CHN–O apparatus (Type 1108, Carlo Erba Instruments), using a sulfanilamide standard.

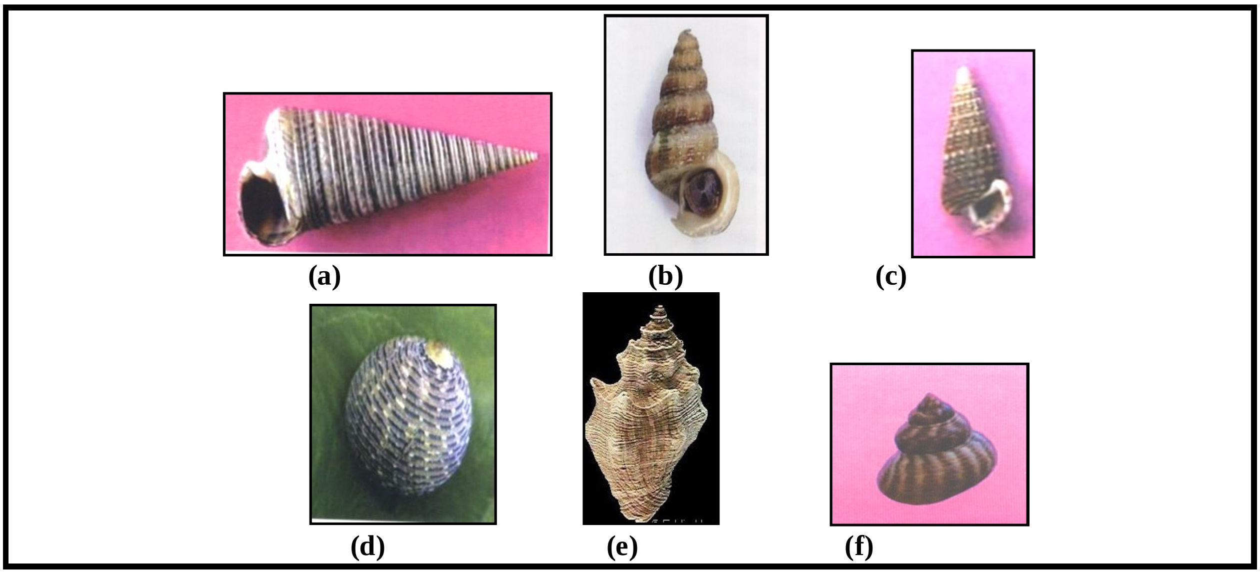

Fig. 1: Dominant gastropod species in mangrove dominated Indian Sundarbans
(a) *Telescopium telescopium*, (b) *Cerithedia obtusa*, (c) *Cerithedia cingulata*, (d) *Nerita articulata*, (e) *Cymia lacera* and (f) *Littorina* spp.

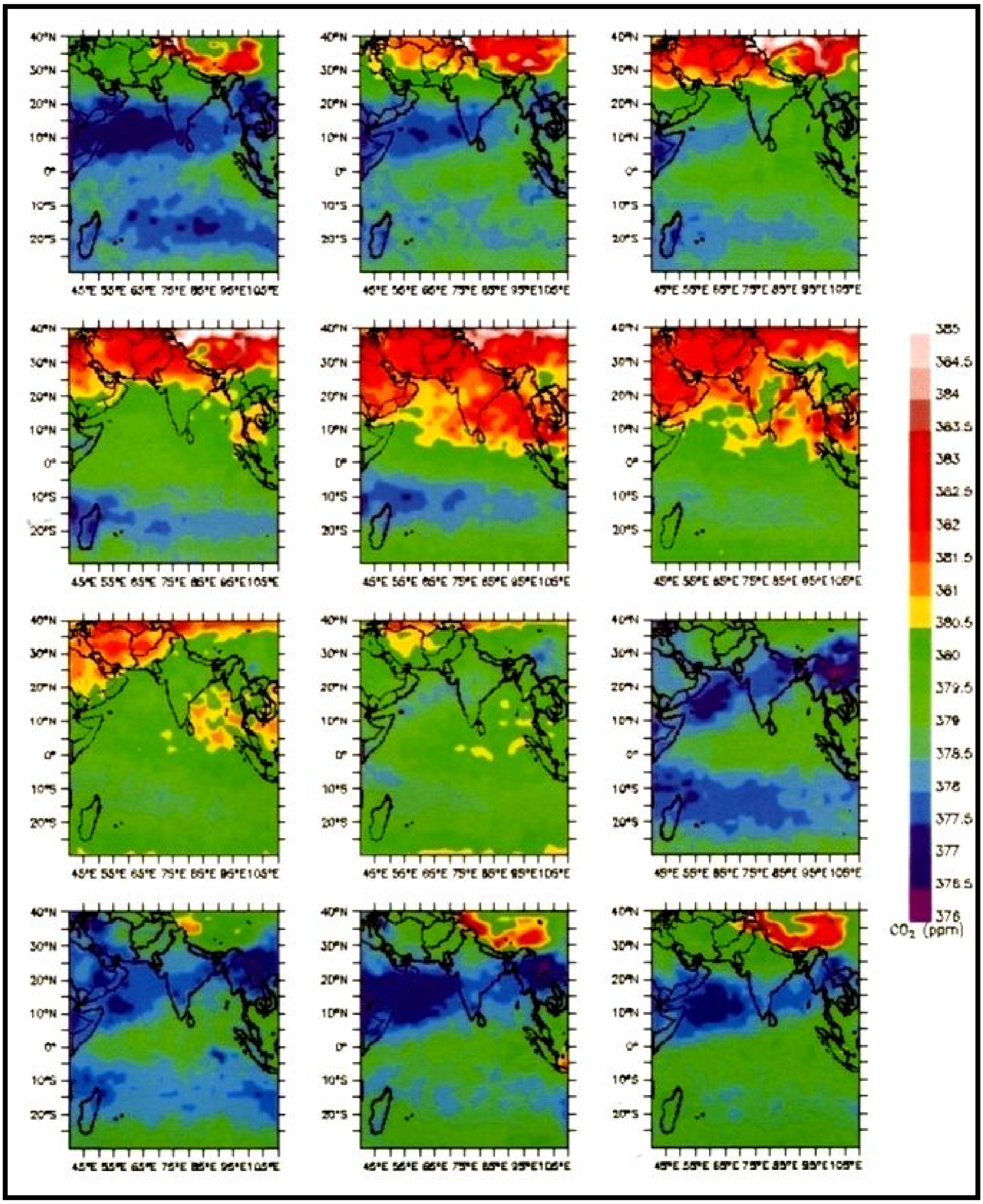

Fig. 2: Monthly climatology of mid-troposphere carbon dioxide over India and surrounding oceans based on AIRS observation during 2003 to 2008 (Source: National Carbon Project Status Report, 2010)[6]

RESULTS

The entire exercise generated the following results:

1. The stored carbon in the gastropods (in % dry wt in tissues) ranges from 32.76 ±1.02 (in *C. cingulata* in western sector of Indian Sundarbans) to 38.37 ±0.91 (in *C. obtusa* in the eastern sector of Indian Sundarbans) (Tables 1-3).

2. Carbon % (dry wt basis) in shell ranges from 12.00 ±0.20 (in *C. cingulata* in western sector of Indian Sundarbans) to 13.99 ±0.12 (in *C. obtusa* in the eastern sector of Indian Sundarbans) (Tables 1-3).
3. The stored carbon is more in the flesh than in the shell (Tables 1-3). This is applicable irrespective of all the gastropod species considered in the present study.
4. There exist significant variations ($p < 0.01$) (Tables 4 and 5) in stored carbon (both in flesh and shell) between species. The order of variation is *C. obtusa*>*N. articulata*>*T. telescopium* >*C. cingulata*.

DISCUSSION

The carbon dioxide concentration over India is gradually increasing over a period of time. The mid-tropospheric carbon dioxide during 2002-2008 retrieved from Atmospheric InfraRed Sounder (AIRS) on board Advanced Microwave Sounding Unit (AMSU-A) was analyzed over the Indian sub-continent and surrounding oceans. Important features exhibited by the observations are the strong seasonal and latitudinal gradient modulated by strong monsoonal activity over the study region (Fig. 2).

Further analysis suggests that atmospheric carbon dioxide concentration has increased linearly from 372 ppm in 2002 to 386 ppm in 2008 at the rate of 2.05 ppm/year during past 6 years over the study region with strong seasonal variation over the land and relatively weaker seasonal variability over the ocean (Fig. 3).

West Bengal, a maritime state in the North East part of India is no exception to this rule. The percentage of increase of carbon dioxide emission in West Bengal is 50.79% from 1980 to 2000 (Fig. 4)[7].

The increase in carbon dioxide in the air of coastal West Bengal is reflected through gradual increase of carbon in the floral community. Data on blue carbon are available in plenty from coastal West Bengal [2, 3, 4, 8, 9], but no researches have yet been carried out on the stored carbon in the endemic faunal community. In the faunal community like shelled organisms food and water are the major sources of carbon in the body. In case of gastropod, which is under phylum mollusca carbon in the body is acquired from four major sources namely atmospheric carbon dioxide, food, water and carbonate rocks. The habitat and nature of food greatly regulate the stored carbon in the gastropod shell and tissues. When these organisms consume and digest food (like algal mat, mangrove leaves, detritus etc. present in the coastal and estuarine region), carbon is introduced to the haemolymph and pass along to the extrapallial fluid in the same way as atmospheric carbon dioxide. Then it mixes with the atmospheric carbon (taken during respiration) and finally shell carbonate is precipitated [10]. Carbon derived from detrital matter and urea (that originate from blue carbon through litter fall) breaks down into ammonia and carbon dioxide through urease reaction [11]. The resulting carbon dioxide is then introduced into the extrapallial fluid and ultimately incorporated into the cell carbonate. The stored carbon percentage in the marine and estuarine gastropod tissue is therefore greatly regulated by the type of food they take. According to some researchers, the stored carbon varies between 25-40% in gastropod that depends on plants or detrital matter[12]. Other scientists pointed out this range of stored carbon between 36-73%[13]. In the present study, the highest stored carbon in *C. obtusa*may be attributed to its dependence on algal mat deposited on the mangrove stem. *N. articulata* depends on both seaweed and detritus for nutrition and therefore exhibits slightly lesser percentage of stored carbon in the tissue and shell. *T. telescopium* and *C. cingulata* are completely detritivorous in nature which may be the reason for their relatively low carbon percentage compared to *C. obtusa*.The results of the present study are almost similar to the findings of otherresearchers (Tables 6-9)[14]. The present study confirms that the primary source of carbon in marine and estuarine gastropods is their diets, which mainly are macroalgae or seaweeds on the mangrove vegetation (preferably on mangrove trunk/stem) or detritus on the intertidal mudflats. *C. obtusa* is fully dependent on algal matter for nutrition and *N. articulata* prefers both algal feed as well as detritus. *T. telescopium* and *C. cingulata* are purely detritivores. Thus the diet spectrum controls the carbon level in gastropods of marine and estuarine environment. The results of the present study strongly advocate the inclusion of gastropods in the blue carbon vertical.

The present study generates few important messages that need to be addressed with long term vision:

1. Molluscs provide a wide array of ecosystem services including biodiversity, food for other members of higher trophic level, livelihood through oyster culture, bioremediation of water and significant carbon sinks.
2. The intertidal mudflats of Indian Sundarbans support a wide spectrum of molluscan species of

which gastropods like *Telescopium telescopium*, *Cerithedia obtusa*, *C. cingulata*, *Nerita articulata*, *Cymia lacera*, *Littorina* spp. *etc*. are dominant in terms of relative abundance.

3. The gastropods are potential storehouse of carbon and the stored carbon is more in flesh compared to hard calcareous outermost shell.
4. The sources of carbon in gastropods are food, water and atmospheric carbon, but the food type regulates the magnitude of carbon in gastropod species in the present geographical locale.
5. The gastropod population is presently under threat as a result of coastal development, aquaculture expansion and over-harvesting (for lime).
6. Because of considerable carbon stocks in gastropods, which are vulnerable to loss with land use as well as the numerous other critical ecosystem services, the species of this molluscan class are of increasing interest for participation in climate change monitoring and mitigation strategies.

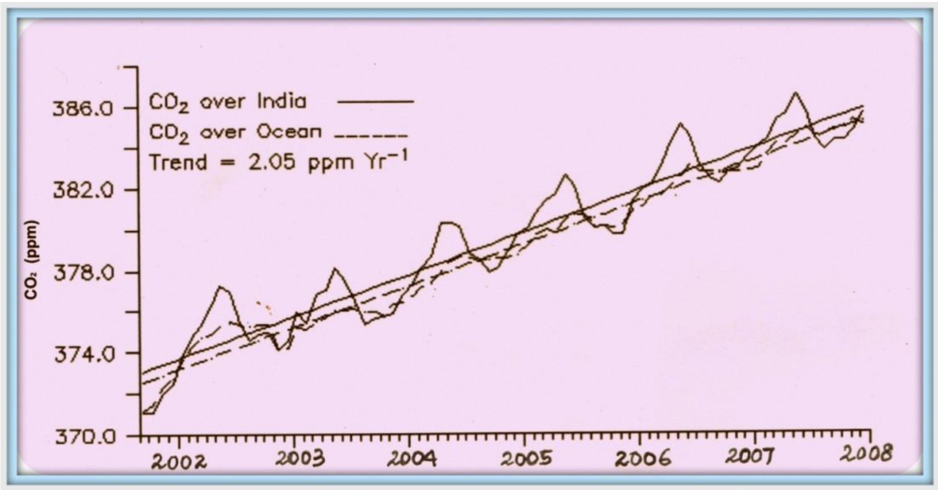

Fig. 3: Trend of mean atmospheric carbon dioxide concentration over India and surrounding oceans (Source: National Carbon Project Status Report, 2010)[6]

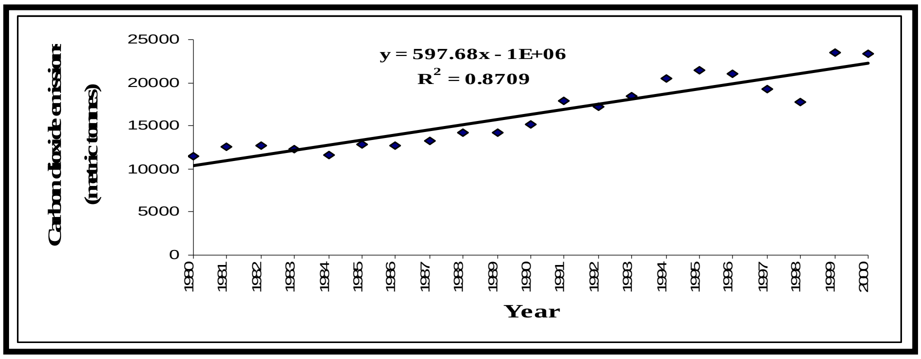

Fig. 4: Estimates of carbon dioxide emissions of West Bengal (metric tonnes of carbon) [7].

Table 1: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations) collected from eastern sector of Indian Sundarbans during April 2013

Species	Carbon	
	Tissues	Shells
Telescopium Telescopium	35.11±0.66	13.10±0.09
Nerita articulate	36.10±0.76	13.78±0.11
Cerithedia obtuse	38.37±0.91	13.99±0.12
Cerithedia cingulate	35.09±0.55	12.66±0.18

Table 2: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations) in the central Indian Sundarbans during April 2013

Species	Carbon	
	Tissues	Shells
Telescopium telescopium	34.44±0.66	12.89±0.09
Nerita articulata	35.28±1.13	13.50±0.10
Cerithedia obtusa	37.37±0.59	13.53±0.04
Cerithedia cingulata	33.77±0.81	12.36±0.07

Table 3: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations) in the western Indian Sundarbans during April 2013

Species	Carbon	
	Tissues	Shells
Telescopium telescopium	32.84±0.78	12.02±0.17
Nerita articulata	33.46±0.93	13.01±0.19
Cerithedia obtusa	35.30±0.90	13.09±0.13
Cerithedia cingulate	32.76±1.02	12.00±0.20

Table 4: ANOVA results showing species and sector wise variation of tissue carbon of the selected gastropod species

Source of Variation	SS	Df	MS	F	p-value	F_{crit}
Between species	18.25	3	6.08	87.45565	2.42×10^{-4}	4.757063
Between sectors	13.59	2	6.79	97.69273	2.64×10^{-4}	5.143253
Error	0.42	6	0.070			
Total	32.26	11				

Table 5: ANOVA results showing species and sector wise variation of shell carbon of the selected gastropod species

Source of Variation	SS	Df	MS	F	P-value	F_{crit}
Betweenspecies	3.05	3	1.02	64.21515	5.96×10^{-4}	4.757063
Betweensectors	1.49	2	0.7	46.96528	0.000216	5.143253
Error	0.09	6	0.02			
Total	4.6	11				

Table 6: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations)

Species	Carbon	
	Tissues	Shells
Morula anaxares (Kiener 1835)	41.46±0.66	11.96±0.04
Orania subnodulosa (Melvill 1893)	46.26±1.13	12.01±0.10
Semiricinula konkanensis (Melvill 1893)	47.38±0.59	14.19±0.09
Purpura bufo (Lamarck 1822)	42.75±0.81	13.76±0.07

Table 7: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations)

Species	Carbon	
	Tissues	Shells
Angaria delphinus (Linnaeus, 1758)	41.43±0.66	12.91±0.08
Trochus maculates (Linnaeus, 1758)	45.27±1.13	12.07±0.17
Haliotis jacknensis (Linnaeus, 1758)	42.36±0.59	13.03±0.03
H. planatae (Sowerby, 1855)	41.71±0.81	11.94±0.12

Table 8: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated gastropod species (mean values and standard deviations)

Species	Carbon	
	Tissues	Shells
Tridacna crocea	41.43±0.66	12.90±0.04
Conus lividus	45.27±1.13	12.09±0.10
Trodus nilotius	42.35±0.59	11.99±0.09
Tridacna squamosa	41.71±0.81	12.94±0.07

Table 9: Concentrations of total carbon (% dry wt) in the soft tissues and shells of the investigated mollusc species (mean values and standard deviations).

Species	Carbon	
	Tissues	Shells
Viviparus viviparus	40.06±0.81	12.73±0.21
Lymnea stagnalis	44.49±2.11	12.85±0.31
Dreissena polymorpha	45.89±0.83	13.12±0.16
Anodonta anatina	35.65±3.37	13.33±0.40

Source: E. Jurkiewicz-Karnakowska, *Polish Journal of Environmental Studies Vol. 14, No. 2 (2005)*, 173-177.

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