# Nature of POC Transport in a Mangrove Ecosystem: A Carbon Stable Isotopic Study

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The isotopic composition of particulate organic carbon (POC) was studied during five tidal cycles in a mangrove creek of Sepetiba Bay, Rio de Janeiro, Brazil. The results show that a mixture of organic carbon from mangrove and marine origins is always present in the creek. Mean mangrove contribution to the POC varied from 16% to 100% and was dependent on tidal amplitude. The results suggest that oceanic carbon can be an important component of carbon balance in mangrove ecosystems. Therefore, earlier carbon balance studies from mangroves which did not include measurements of carbon isotopic composition should be interpreted with care.

## Introduction

Carbon stable isotope measurements have been used as a consistent tracer of organic carbon in mass balance studies in salt marsh and seagrass beds (Haines, 1977*a*; Nixon, 1980; Zieman *et al.*, 1984). Stable isotopes have been used as well to characterize suspended organic matter in coastal waters (Haines, 1977*b*; Odum, 1984), to trace coastal food webs (Haines & Montague, 1979) and the sources of soil and sediment organic carbon (Craig, 1957). However, very few data exist on the carbon isotopic composition of mangrove organic matter (Zieman *et al.*, 1984; Lacerda *et al.*, 1986; Rodelli *et al.*, 1984).

To use such a tracer, the different carbon sources should present different ratios of $^{13}C/^{12}C$ and must maintain such differences both temporally and spatially. Zieman *et al.* (1984), showed that several primary producers present significant spatial variation in their $^{13}C/^{12}C$ ratios (e.g. *Tallassia testudinium*). He also reported that algae present significant differences among species and that the long-term organic matter diagenesis in soils and sediments may also affect the $^{13}C/^{12}C$ ratios. However, the isotopic composition of mangrove plants does not show any significant spatial variability.

Zieman *et al.* (1984) reported $^{13}C/^{12}C$ values for *Rhizophora mangle*, in Florida similar to those found by Lacerda *et al.* (1986) in the same species analysed in Brazil ($c$ −27·6‰).

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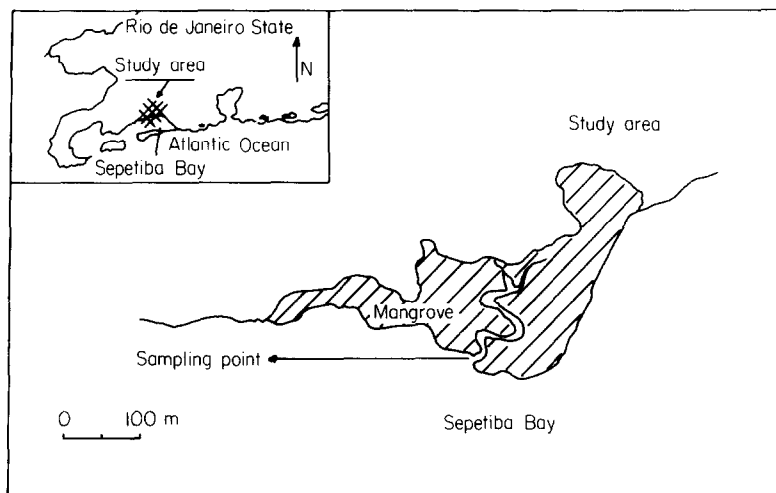
Figure 1. Map showing location of the area studied and sampling point.

Similar values ($-27 \cdot 1‰$) have also been reported for Malaysian mangroves (Rodelli *et al.*, 1984). Temporal variability or variation due to early diagenetic processes of mangrove organic matter have not yet been studied. However, if they do exist they play an insignificant role during the residence time of particulate organic carbon (POC) in mangrove creeks. Any changes in $^{13}C/^{12}C$ ratios of POC should indicate different proportions of the carbon sources. This paper describes the carbon isotopic composition of POC fluxing from a mangrove forest and its tidal variability in Sepetiba Bay, Brazil, being part of a long-term study on the carbon balance in mangrove ecosystems (Lacerda *et al.*, 1988).

## Materials and methods

Samples were collected during five tidal cycles in March and June 1987 from a tidal creek draining a 4 ha mangrove forest in Sepetiba Bay, Brazil. This area is located 100 km from Rio de Janeiro at longitude 43:33:44 W, 44:02:30 W and latitude 22:54:06 S, 23:04:18 S (Figure 1). *Rhizophora mangle* L. is the dominant tree species with only a few occurrences of *Laguncularia racemosa* L. Gaerth and *Avicennia shaueriana* Stapt and Leech (Silva, 1988). Litter fall rate in the forest was reported as $5 \cdot 2$ tonnes C ha$^{-1}$ year$^{-1}$ with an above ground biomass of 65 tonnes C ha$^{-1}$ (Silva, 1988). The major carbon export pathway from this forest has been reported as POC (Rezende, 1988). Freshwater inputs as well as terrestrially derived carbon and nutrients to the forest are mostly due to runoff, they are however quantitatively insignificant (Ovalle *et al.*, 1987).

The POC was sampled at 30 minute intervals by means of a Van Dorn bottle in the centre of the creek. Two litres of water were collected and filtered through a pre-weighed GFC glass fibre filter. Filters were packed in aluminium foil and frozen in the field. At the laboratory they were dried (60 °C, 48 h), producing 15 to 70 mg l$^{-1}$ of suspended matter. Leaf samples of mangrove trees as well as suspended matter from the open Sepetiba Bay and from the interior of the forest were also collected for analysis.

Samples were prepared by combustion of the filters with pre-combusted CuO in sealed evacuated pyrex break-seal tubes. The samples were combusted overnight at 550 °C and the $CO_2$ purified cryogenically using an alcohol–dry ice trap. The stripped and purified

TABLE 1. $^{13}C/^{12}C$ ratios in samples from Sepetiba Bay mangrove forest. Values are means of three samples for each component

| Leaves | $^{13}C/^{12}C$ ‰, PDB |
| --- | --- |
| R. mangle | −27·60 |
| A. shaueriana | −27·41 |
| L. racemosa | −25·15 |
| Mean of leaves | −26·72 |
| Marine POC | −20·50 |
| Mangrove POC | −26·77 |

$CO_2$ sample was collected in a tube under liquid nitrogen in a high vacuum line. Isotopic ratios were determined using a Micromass model spectrometer. All $^{13}C/^{12}C$ values are reported relative to PDB limestone standard as in equation (1):

$$^{13}C/^{12}C = \frac{(^{13}C/^{12}C) \ \text{sample}}{(^{13}C/^{12}C) \ \text{PDB} \ \text{standard}} \ 1 \times 10^3. \tag{1}$$

Quantification of the relative contribution of Bay's (marine) and mangrove POC in suspended matter was calculated according to a two-end-member model following equation (2):

$$\% \ \text{Mangrove POC} = \frac{(^{13}C/^{12}C) \ \text{sample} - (^{13}C/^{12}C) \ \text{marine}}{(^{13}C/^{12}C) \ \text{mangrove} - (^{13}C/^{12}C) \ \text{marine}} \times 100. \tag{2}$$

### Results and discussion

Isotopic carbon compositions for the various samples are presented in Table 1. The isotopic composition of leaves from mangrove species are very similar, with a mean value of −26·72‰, and also similar to other mangrove values published elsewhere (e.g. Zieman et al., 1984; Rodelli et al., 1984). Mangrove and marine suspended matter however presented differences in their carbon isotopic ratios.

While marine POC from Sepetiba Bay was similar to the mean isotopic ratio of marine organic carbon, as −21·00‰, reported by Fry and Sherr (1984), mangrove POC presented much lower values, similar to the mean value found for mangrove leaves in the area. This result allows characterization of two typical end-members: the marine POC (−20·50‰) and the mangrove POC (−26·8‰). These values will be used in further calculations in this paper.

Figure 2 shows the variability of $^{13}C/^{12}C$ ratios in suspended matter during the five tidal cycles sampled. In all cycles the results show the same pattern, with ebb-peak values close to mangrove POC, whereas around flood-peaks the $^{13}C/^{12}C$ ratio shifts towards the marine POC value. These fluctuations characterize the change of POC origin during different stages of a tidal cycle. This is clearly seen in Figure 2 which represents a large amplitude tidal cycle. By using equation (2) we can calculate that on 17 March 1987 during a large amplitude tidal cycle, the mangrove contribution during ebb peaks reached up to 100% of the POC transported, whereas during flood tide peaks the marine contribution dominated
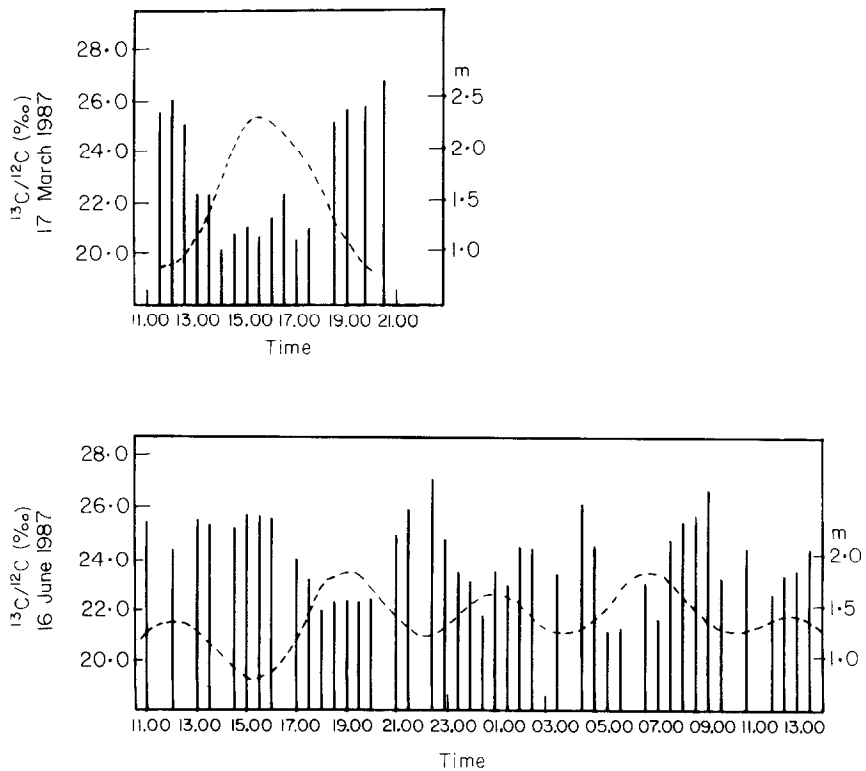
Figure 2. Detailed (30 minute intervals) variation of $^{13}C/^{12}C$ ratio of suspended matter during five tidal cycles. Bars indicate $^{13}C/^{12}C$ ratios. Dotted lines indicate creek depth.

with mangrove POC contribution only 2 to 30%. In general, the mean isotopic composition observed during the flood period of this tidal cycle was −21·80‰, corresponding to 21% of mangrove POC, and during ebb tide the mean ratio was −24·60‰ reflecting a mangrove contribution of 65%. Lacerda et al. (1988) sampling two tidal cycles in the same region observed similar behaviour for large amplitude tidal cycles.

The sampling period of 16 July 1987 included four tide cycles with much lower amplitudes compared to the cycle discussed above. Although variability of the $^{13}C/^{12}C$ ratio was not so marked, the same pattern was observed, with $^{13}C/^{12}C$ values being lower around ebb tide peaks (mangrove POC dominant), and high values at flood tide peaks (marine POC dominant). The smaller variability could be associated with differences in tidal amplitudes between cycles which would influence the total flooded area and the efficiency of transport during each tidal cycle.

In these lower amplitude cycles, carbon isotopic composition during flood periods varied between −21·20‰ to −26·00‰, with a mean of −23·60‰, corresponding to a mangrove contribution of c 49%. During ebb tide, values ranged from −21·50 to −27·30‰, with a mean of −24·70‰, reflecting a mangrove percentual contribution of c 16%.

Although fluctuations of mangrove POC within these tidal cycles exist, it is clear that during large amplitude tidal cycles mangrove contribution to creek POC is highest while during low amplitude tidal cycles mangrove contribution to creek POC is lowest. However, net export of mangrove carbon can only be assessed with mass balance data.

During both sampling periods, the shift of carbon sources did not occur immediately after tidal changes, an average of 1 hour intervals occur before typical $^{13}C/^{12}C$ values of ebb and flood periods are achieved, indicating that a certain fraction of POC is constantly moving in and out of the system.

Concluding, the results show that a significant part, but not the totality, of the POC exported from the system is of mangrove origin. However, even during large amplitude ebb periods, when the contribution of mangrove POC is maximum, an important fraction of marine POC is also present. All studies of actual measurements of carbon export from mangroves have considered the mangrove tidal creeks. Therefore, the results strongly suggest that most previous estimated POC export rates from mangroves to adjacent coastal waters, should be interpreted with care.

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