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Plankton dynamics at Itamaracá mangrove estuarine system, Pernambuco, Brazil

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Abstract

Plankton dynamics was studied at Itamaracá mangrove to assess the estuarine-coastal interactions. Sampling was carried out at the north and south connections with the Atlantic Ocean in 1994, and in two perpendicular profiles toward offshore, in March 1995. Water masses at Itamaracá had an average temperature of 28.6°C; salinities varied from 19.62 to 36.99 and dissolved oxygen was supersaturated at high tide and under 70% saturation at low tide. The Tropical Water Mass characterized the shelf area. High overall nutrient concentrations indicated a eutrophic estuarine area resulting in a high primary productivity (between 2 and 39mgC.h^{-1}.m^{-3}) and high chlorophyll-a (mean: 12mg.m^{-3}) abruptly decreasing offshore. Identified were 78 phytoplankton species to Santa Cruz channel inlets and 102 species to shelf waters. Nitrogen was the limiting factor with a N:P ratio of less than 10:1. Seventy microzooplankton and 49 macrozooplankton taxa were identified to Santa Cruz inlets while 98 microzooplankton and 86 macrozooplankton taxa occurred in the shelf area; Part of the nutrients and organisms were exported from Itamaracá estuarine system to the adjacent shelf at low tide. It was confirmed that the role of mangrove are source of energy and organisms to estuarine and marine food webs.

1 Introduction

A large project on the ecology of Santa Cruz Channel, the core of Itamaracá estuarine system (IES), was conducted by the Department of Oceanography of the Federal University of Pernambuco and the Center for Tropical Ecology, Bremen (Germany). Various aspects of the hydrography, fauna and flora have been studied during this project [1,2,3,4,5,6,7]. Before the start of this project in 1993, there was a large bulk of knowledge about this ecosystem [8], and it is among the best investigated littoral of Northeastern Brazil. This ecosystem has a socio-economical importance to Pernambuco State and there is a critical need to understand its functioning because of the rate at which these areas are being converted to land uses.

The function of mangrove either as a source or sink of organic matter and nutrients, depends on the net flux of materials across the boundary estuary-coastal water. This boundary is somewhat undefined since estuarine water can extend into continental shelf during periods of high freshwater discharge. Thus the coupling of mangroves to estuarine and coastal waters involves exchange across the mangrove-estuary boundary, followed by transport from the estuary to coastal waters [9].

The Itamaracá mangrove estuary is used as nursery grounds by many commercially important species and this has generally been attributed to the abundant food supply in comparison to adjacent marine areas [7, 10].

The plankton is a good key group to understand fluxes in marine-estuarine systems, because a large number of benthic and nektonic adults spend part of their life in the zooplankton, and as such the plankton stage influences the distribution and abundance of adult populations.

The objective of the present study was to investigate the mangrove estuarine system influence on coastal plankton diversity and abundance, and the export processes.

2 Material and methods

The Itamaracá estuarine system is located at 7°34'00"- 7°55'16" S and 34°48'48" - 34°52'24" W, about 50 km north of Recife, Pernambuco State, Brazil. It consists of the U-shaped Santa Cruz Channel with 20km length; and there are two connections to the South Atlantic Ocean and five tributaries draining into the channel (Figure 1).

Samples for hydrology and plankton were collected at 3 hour intervals, during 24 hours, in 2 transects (3 fixed stations in each) at the north (Catuama) and south (Orange) inlets in the rainy (May/1994) and dry (December/1994) seasons; and at two perpendicular profiles (3 fixed stations each) to Orange (St.31, St.32, St.33) and Catuama (St.37, St.38, St.39) inlets in March/1995.

Hydrological data were collected at the surface with a Nansen bottle. *Water temperature* - reversion thermometer affixed to Nansen bottle; *salinity* - Mohr-Knudsen method [11]; *pH* - Beckman Zeromatic II pHmeter; *dissolved oxygen* - Winkler method [11]; *nutrients* [11]; *water transparency* - Secchi disc. Samples for the determination of Chlorophyll-a were collected with a 1-litre Van Dorn bottle at the surface. Chlorophyll-a was measured according to Strickland

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and Parsons [12]. Phytoplankton primary productivity was measured through the ^{14}C method [13].

Phytoplankton was collected with a Van Dorn bottle and samples preserved in Lugol's solution. The Utermöhl method [14] was used to quantify and identify taxa under an inverted microscope. Zooplankton sampling at Santa Cruz Channel inlets were done with two standard plankton nets with mesh size of 50 and 300 micrometers, corresponding to micro- and macrozooplankton, respectively; five minutes horizontal subsurface hauls were made at each station. At the coastal perpendicular profiles to inlets a Bongo net (mesh size 50 and 300 micrometers) were hauled obliquely at a speed of 2 to 2.5 knots from a depth between 14m in nearshore and 50m in offshore station.

A flowmeter (Hydrobios, Kiel) was fitted onto the opening of all the net used. Samples were preserved in a 4% buffered formalin/seawater solution. Plankton biomass was obtained by the wet weight method. Zooplankton species were identified until the lowest taxonomic unit possible and taxon abundance (org.m^{-3}) counted under a Standard microscope for microzooplankton (1 ml) and stereomicroscope for macrozooplankton (4 ml). These subsamples were taken with a Stempel-pipette of each the entire sample (250 ml).

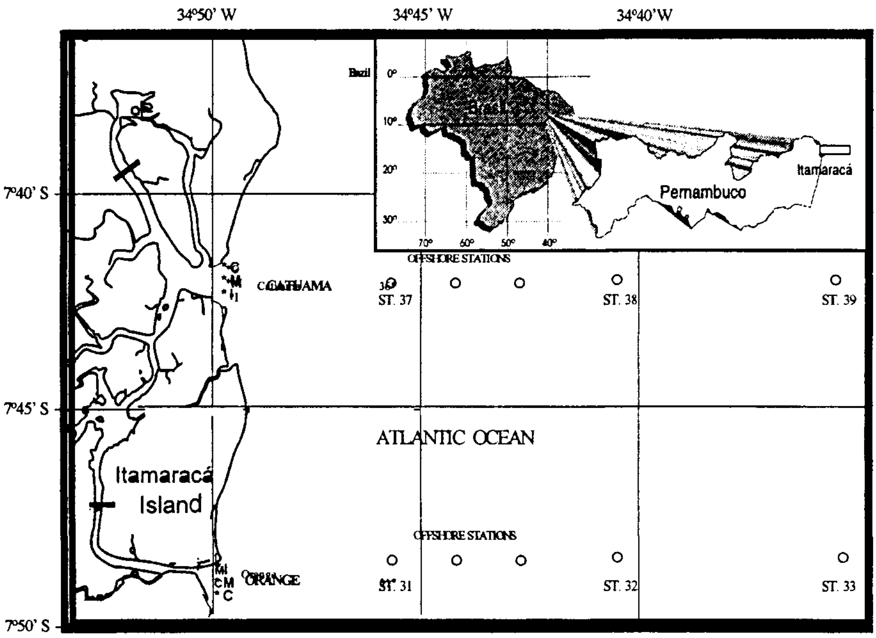

Figure 1: Itamaracá area, coast of Pernambuco, Brazil, showing sampling stations at Santa Cruz Channel inlets and at costal area. I=Island, M=middle, C= Continental Stations.

3 Results

3.1 Hydrology

At Itamaracá system lowest water temperatures (minimum 27.34°C) were measured in rainy season (May/94) and highest temperatures (maximum 30.92 °C) in dry season (December/94). No thermal stratification was observed. At shelf waters temperatures varied from 26.2°C to 29.0°C. Salinity at Santa Cruz inlets varied from a minimum of 19.62 in rainy season (May/94) to a maximum of 36.99 in dry season (December/94). High tide presented higher values. Vertical stratification was restricted to the rainy season when a flushing of the estuary by freshwater occurred. Due the width of the outer estuary horizontal stratification was common. The salinity regime is euhaline-polyhaline indicating strong marine influence. At the shelf salinity varied from 36.6 to 37.8. At Santa Cruz inlets dissolved oxygen (DO) ranged from 3.42 $ml.L^{-1}$ (69% saturation) to 7.02 $ml.L^{-1}$ (155% saturation) both at rainy season. Significant oxygen depletion was found during low tides for much of the seasons. At shelf stations, DO values were higher and over saturated (Figure 2).

PH were above 7 in all stations. Water transparency at inlets was reduced during the rainy season (minimum of 0.9 m) due intensive fine clay resuspension. Shelf waters presented high transparency. Nutrients (NO_2, NO_3, PO_4 and Si O_4) at inlets were variable, but in general nitrate was highest in the rainy season and the others in the dry season, both at ebb and low tides. Nutrient levels generally were indicative of eutrophy. At shelf waters nutrient salt concentrations were very low, indicative of oligotrophy.

3.2 Primary production and Chlorophyll-a

At Santa Cruz channel the primary productivity varied from 2.25 $mgC.h^{-1}.m^{-3}$ to 39.00 $mgC.h^{-1}.m^{-3}$. Lower values were found at Catuama inlet, during low tide and higher values at Orange inlet at ebb tide, both during the rainy season. The average values for Catuama during the rainy and dry season were 10.63 $mgC.h^{-1}.m^{-3}$ and 9.93 $mgC.h^{-1}.m^{-3}$, respectively; at Orange inlet values for the rainy and dry seasons were 20.43 $mgC.h^{-1}.m^{-3}$ and 17.19 $mgC.h^{-1}.m^{-3}$ (Figure 3). At shelf transects the primary production was very low (< 1.0 $mgC.h^{-1}.m^{-3}$).

The Santa Cruz inlets showed high chlorophyll-a concentration (average values 12.0 $mg.m^{-3}$); Orange inlet and rainy season had higher amounts. At shelf transects the chlorophyll-a horizontal distribution decreased from an average concentration of 0.34 $mg.m^{-3}$ at coastal station to 0.01$mg.m^{-3}$ at offshore stations.

3.3 Phytoplankton

A total of 78 species were identified to Santa Cruz channel inlets contributing the diatoms to 85% of the community. Phytoplankton density was maximum at

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the south inlet during the rainy season (4,460,000 cel.l^{-1}). *Thalassiosira* sp, *Coscinodiscus* sp, *Guinardia stolterfothii* and *Amphora arenaria* were dominant at Orange inlet; and Phytoflagellata, *Chaetoceros lorenzianus* and *Asterionellopsis glacilis* at Catuama inlet.

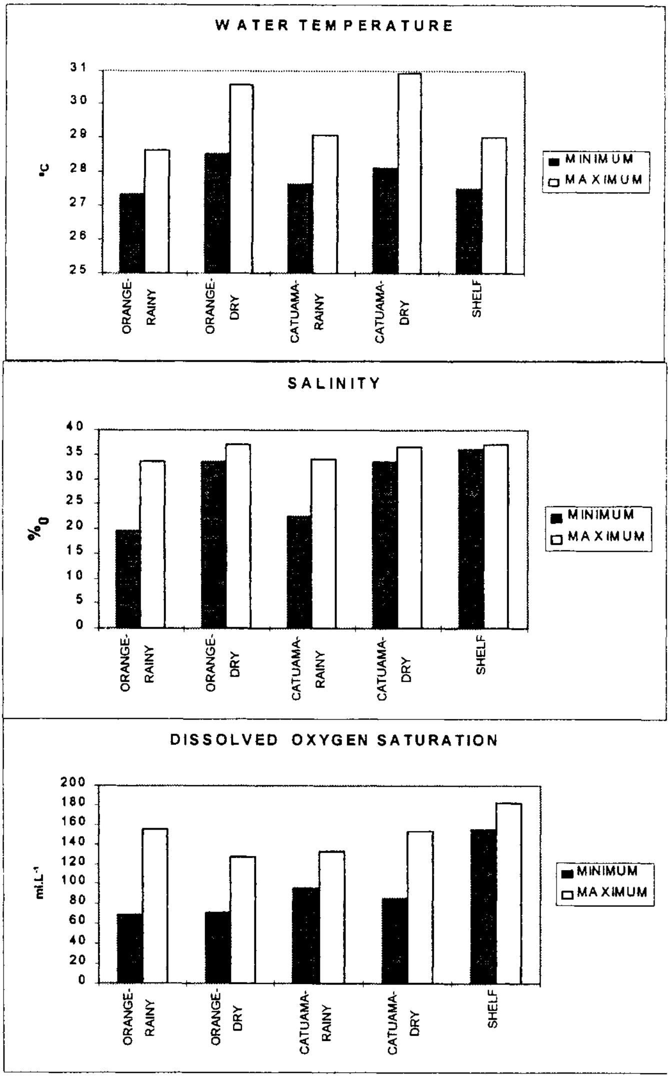

Figure 2: Water temperature, salinity and dissolved oxygen (% saturation) in the Itamaracá estuarine system, in May/1994 (rainy season), December/1994 (dry season) and at coastal area (March/1995).

Average values can be seen in figure 3. Nitrogen was the limiting nutrient at the ecosystem with a N:P relation lower than 10:1. Benthic diatoms (littoral) contributed with 32,72% of the community.

At shelf waters a total of 102 species were identified of which diatoms presented 51 species and 1 variety. The most abundant were *Streptothaca thamensis*, *Rhizosolenia imbricata* var. *shrubsolei*, *Rhizosolenia styliformis* and *Asterionella notata*; dinoflagellates were present with 45 species and 1 variety with *Ceratium massiliense*, *Ceratium tripos* and *Ceratium vultur* var. *vultur* as most abundant; and 2 cyanophyceans species, predominating *Oscillatoria erythraeum*. A fourth group of unidentified phytoflagellates was also registered. The density ranged from 50,000 cel.l^{-1} to 590,000 cel.l^{-1}. A sharp decrease in phytoplankton abundance from both inlets to offshore was observed (Figure 4).

3.4 Microzooplankton

Seventy taxa were collected at the Santa Cruz inlets. Besides holoplanktonic (76%) and meroplanktonic (20%) organisms, it was registered the tychoplankton (4%) mainly Foraminifera, reflecting the shallowness of the estuary and tides turbulence. The zooplankton was essentially composed of typical marine euryhaline species. The most diversified taxon was Copepoda (27 species) followed by Tintinnina (15 species). The most common Copepoda were *Parvocalanus crassirostris, Acartia lilljeborgi, Oithona hebes* and *Euterpina acutrifrons*, in all life cycle stages. High numbers of meroplanktonic larvae of Bivalvia, Gastropoda and Polychaeta were registered. Microzooplankton was more abundant at Orange (south inlet) during rainy season (Figure 3). The minimum density (22,449 org.m^{-3}) was at dry season and maximum (244,216 org.m^{-3}) was during rainy season, both at flood tide.

At shelf waters microzooplankton presented 98 taxa. Copepoda was most abundant (46 species). *Undinula vulgaris*, *Nanocalanus minor*, *Scolecitrix danae* and *Eucalanus pileatus* presented high density. The microzooplankton abundance decreased abruptly from coast to offshore (Figure 4). The low zooplankton density shows the area oligotrophy few miles from coast.

3.5 Macrozooplankton

Forty-nine macrozooplankton taxa were registered at the Santa Cruz inlets. The most abundant taxa were Copepoda, Brachyura zoeae and Cirripedia nauplii, followed by adult *Lucifer*, Chaetognatha, Larvacea, fish eggs, Gastropoda and Upogebidae zoeae. The remaining taxa showed mean densities lower than 10 ind.m^{-3}. Ctenophora density was higher during the dry season.

The zooplankton community structure at shelf transect showed a clear gradient, with high biomass at coastal area sharply decreasing seaward (Figure 4). Eight-six taxa were recorded. Copepoda dominated by abundance in most stations.

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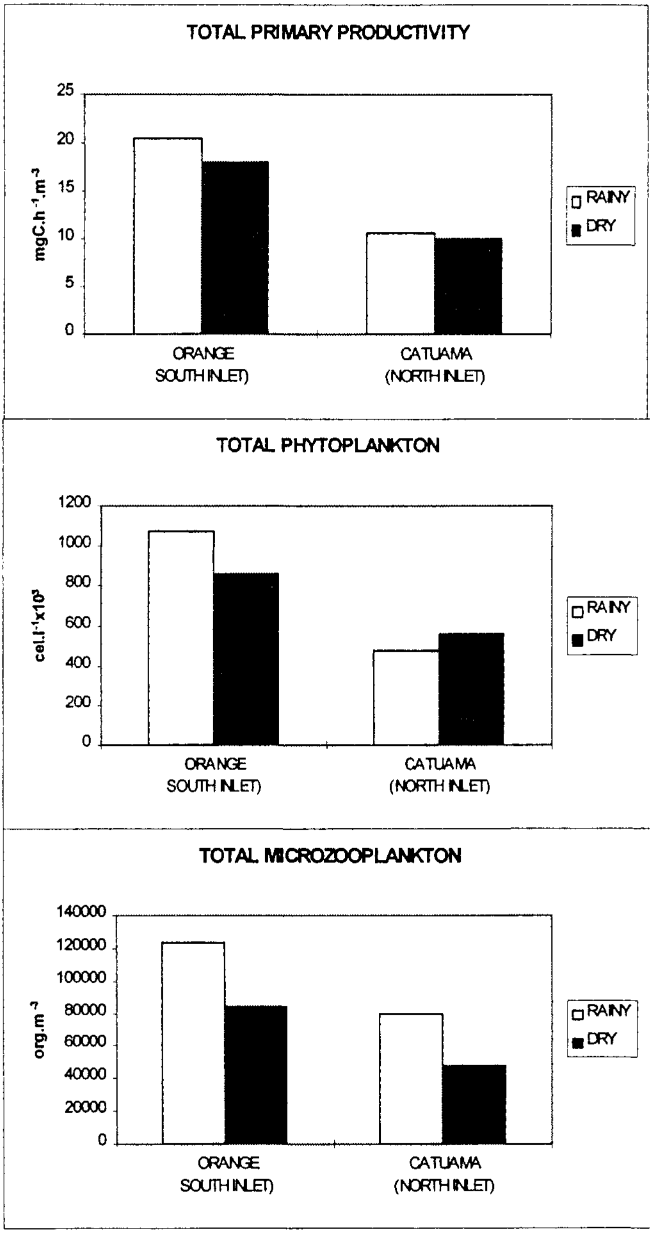

Figure 3: Average primary productivity, phytoplankton and microzooplankton in the Itamaracá estuarine system, in May/1994 (rainy season) and in December/1994 (dry season).

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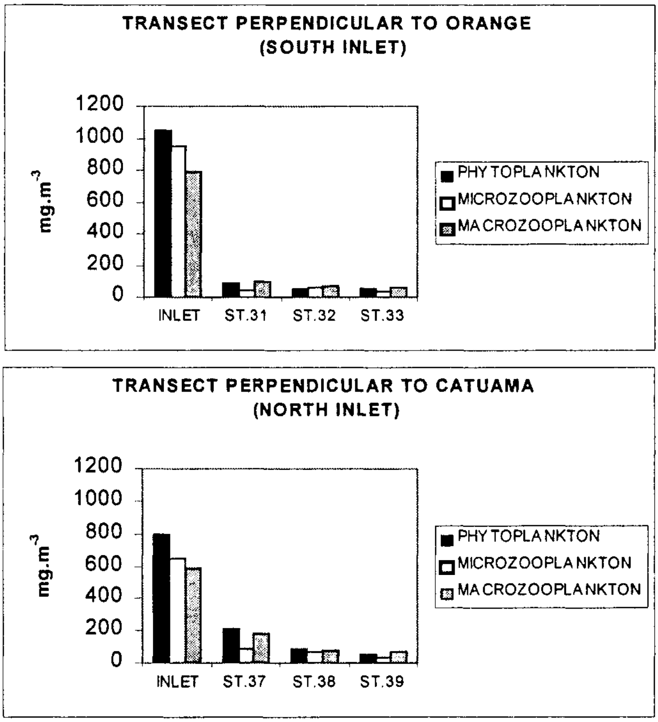

Figure 4: Total biomass of phytoplankton, microzooplankton and macrozooplankton in the Itamaracá estuarine system inlets (1994) and at shelf transects 1995).

At both transects the abundance of decapods larvae was highest at the most nearshore stations and decreased towards the shelf edge. Among decapods larvae, Brachyura and Porcellanidae zoeae were the most abundant taxa at the nearshore stations. Chaetognathas were also abundant at nearshore stations.

4 Discussion

The estuaries are trophically connected with the surrounding intertidal mangrove forests as a source of organic matter, nutrients and organisms among others. Leaf litter on the forest floor represents a major source of organic matter and nutrients outwelling from mangroves to adjacent waters [9]. However, it was observed a small mangrove influence at the nearshore shelf of Itamaracá during the dry season. The sandstone reef act as a topographic barrier, separating the IES from shelf waters.

The Itamaracá estuarine system (IES) presented lower salinities than the shelf waters. The lower salinities of IES waters are due to the freshwater runoff from the 824km^2 large drainage basin, which varies between 0.19 and 57.7m^3.s^{-1} in the dry and rainy seasons, respectively [15].

The high loads of nutrients at Itamaracá ecosystem due to anthropogenic inputs have caused increases in water column phytoplankton primary production. Since high nutrient concentrations were characteristic of the turbid, lower salinity waters, during rainy season, productivity should be light limited. However, during the rainy season primary productivity and Chlorophyll-a were higher. On the other hand, the N:P relation showed nitrogen to be limiting to phytoplankton [5], which was very high at both Santa Cruz channel inlets and had a sharp decrease seaward.

The stable isotope measurements of zooplankton and particulate organic matter [7] showed a clear boundary between estuarine plumes at IES and nearshore shelf stations. A significant export of particulate organic matter from IES to the nearshore shelf was not observed at dry season.

In spite of the sharp hydrological border, mangroves showed to influence plankton composition at the nearshore shelf. Clear differences in plankton biomass and community structure were discernible between nearshore and offshore stations. At nearshore decapods larvae were even more abundant than copepods. Among decapods larvae, brachyuran and porcellanid zoeae were the most abundant taxa at nearshore stations [7]. Since extremely high abundances of these zoeae are typical of mangrove estuaries [16, 17, 18] the community structure pattern described above hints at an export of organisms from mangrove to nearshore shelf waters. This export would be limited to a coastal parallel band, 10-20 km wide [7]. Offshore abundances and biomasses found at the shelf transects are extremely low, typical for tropical oceanic plankton.

Taxonomic composition of brachyuran zoeae supported the assumption that high abundances of this group nearshore are due to export from mangrove estuaries; and as shown by Schwamborn [7], 81% of these larvae were collect in the estuarine plumes. Wehrenberg [6] calculated an overall export from the Santa Cruz inlets of 1.5x10^8 zoeae per day. Since decapod larvae and copepods are an important food for many fish species [19, 20, 21], their export from mangroves to the shelf means an important input to marine food webs.

Most estuarine zooplankton collected with plankton net are thought to be herbivorous, grazing on phytoplankton, and include most of the holoplankton and a great part of the meroplankton [22]. The proportion of the available phytoplankton grazed varies widely. Some authors [23, 24] estimated about 45% to 50% of the planktonic primary production consumption by zooplankton, while others [25, 26] suggested food consumption by zooplankton between 2-13% of the phytoplankton standing crop.

Sautour *et al.* [21] suggested that in the plume of dilution of the Gironde estuary (France) most of the phytoplankton production was not grazed by late stage copepods during early spring. The trophic fate of phytoplankton depended on its size structure: small cells were mostly grazed by microzooplankton and supported a "microbial-type" food web; and larger cells were ingested by large particle feeders and supported a classical food chain. At IES occurred an inverse

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correlation between nanophytoflagellates and microzooplankton; and during higher abundance of brachyuran larvae a decrease on copepods was registered, possible due to grazing effects.

At IES, the importance of mangrove detritus for the macrozooplankton was demonstrated by Schwamborn [7] through stable isotopic analysis and laboratory feeding experiments. Stable isotope measurements have shown that an amount of 13% to 40% assimilated carbon of mangrove was assimilated by estuarine copepods. Various decapod postlarvae showed carbon isotopes similar to phytoplankton, indicating that mangrove detritus does not play a major role in their nutrition.

The importance of mangrove ecosystems as a source of energy and organisms for tropical estuarine and marine food webs is in part confirmed by the present study. Mangrove carbon enters estuarine pelagic food webs at Itamaracá additionally to carbon derived from primary productivity of microalgae.

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