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SHORT NOTE

Primary productivity in the water column of Estero Morales, a mangrove system in the Gulf of Nicoya, Costa Rica

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Abstract: Primary productivity was measured in the estuary Estero Morales during 15 months (1990-1991). Water column primary productivity was determined using the dissolved oxygen method at two different depths (I=50% and I=10%) at each research site and during two consecutive days of sampling . Rosettes were incubated for five hours with three clear bottles and two dark bottles. The Winkler method was used to determine dissolved oxygen. Primary productivity was also measured with lower sampling frequency at the Cortezas Islands to obtain a point of comparison. These sites are all located in the Gulf of Nicoya, Costa Rica (10°N, 85°W). Water column net primary productivity in Estero Morales presented average values from 1.20 ± 0.70 g C/m^2 d (around 450g C/m^2 year). Values obtained from Islas Cortezas were around 1.69 gC / m^2 d. There was a significant difference between the dry and rainy seasons with respect to net primary productivity ($z=2.196$, $p<0.03$). Another significant difference was determined between the depths I=50% and I=10% in terms of net primary productivity ($z=2.51$, $p<0.006$). The values obtained for primary productivity establish Nicoya Gulf as one of the most productive estuaries in the world. A follow-up study is recommended for this area, consisting of simultaneous sampling at different points of the Gulf of Nicoya. These samples should be taken at a minimum of five different incubation depths for each sample in order to obtain more detailed information in calculating productivity by layers in water column. It is also recommended that frequency of sampling be increased for greater assurance that results are not produced by the distribution of patches of phytoplankton.

Key words: Primary productivity, dissolved oxygen, tropical estuary, water column.

Numerous studies have been performed with reference to quantitative, spatial and temporal variability of individuals and species, both in benthonic communities and planktonic associations of estuaries and coastal systems (Mandelli & Ferraz de Reyes 1982, Cloern 1987, Vargas 1988). However, energy flow in the community represents a little explored field of research in tropical areas (Alongi 1989). A basic component of study in the function of communities, primary productivity is understood as the synthesis of organic material with high potency chemical energy, by substances of lower potency chemical energy (Raymond 1980) by a given unit of time. Primary productivity is generally indicated in g C/m^2 per day or in g C/m^2 per year. In the literature it is occasionally expressed in units of organic material per volume and unit of time (g C/m^3 day) (Bodungen *et al.* 1985). Studies most often use the former since it integrates primary productivity by layers, measured in vertical units of area in a water column. Water column primary productivity (in terms of biomass) is one of the principal sources of energy for the majority of estuary ecosystems around the world (Day *et al.* 1989). In addition, an empirical corollary has been determined between primary productivity and fish productivity in a wide variety of marine systems (Nixon 1982; Mallin *et al.* 1991). There are relatively few studies on associations of phytoplankton and water column primary productivity in neotropical areas (Revelante and Gilmartin 1982). In Latin América, research has been performed by Mandelli and Ferraz de Reyes (1982) in a tropical inlet (Venezuela), with averages between 200 and 230 g C/m^2 per year; as well as Brandini (1985), in Paranaguá (Brazil); and D'Croz *et al.* (1991), in a tropical bay (Panamá). There are even fewer investigations that take into account the annual cycle of estuaries, given the great deal of time and effort needed to obtain suitable temporal and spatial measurements (Cole 1989).

This research took place at three sites: inside the main channel of Estero Morales (A), at the mouth of this same estuary (B) and at the Cortezas Islands (C) (Fig.1) over a period of 14 months (October 1990 to December 1991). Depths of incubation samples were selected on the basis of the depth of the Secchi disk and on the sunlight extinction equation: $Iz = Io \cdot e^{-kz}$ (Io is the luminous intensity hitting the surface of the water, Iz corresponds to the luminous intensity at a determined "Secchi depth"(z) and k is the extinction coefficient-taken in this case, where waters are turbid, as k=1.7/z) (Holmes 1970). Water column primary productivity was determined using the dissolved oxygen method (Hall & Moll 1975)

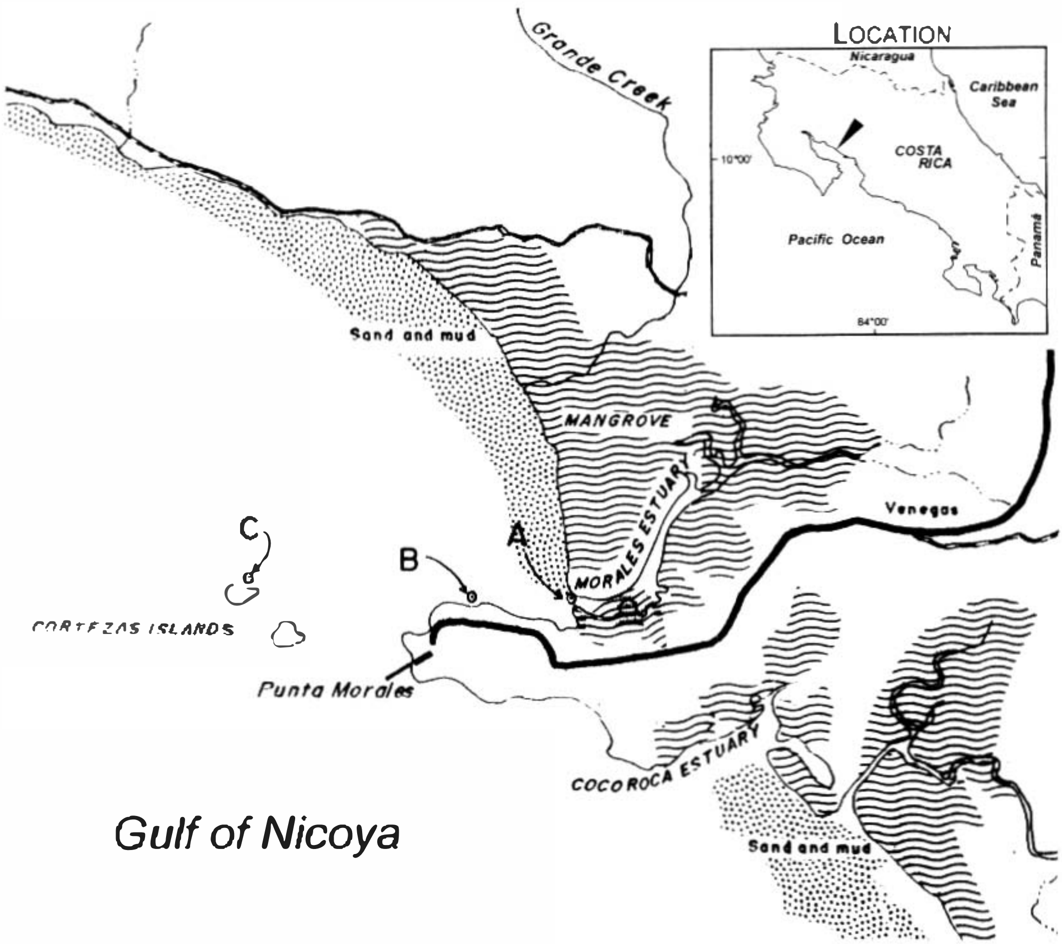

Fig. 1. Study site in the Gulf of Nicoya, Costa Rica where primary productivity measures where taken during a period of 15 months between 1990 and 1992.

at two different depths: I=50% and I=10% of luminous intensity hitting the surface water. This sampling was perfomed at each research site and during two consecutive days and at inflowing water. Rosettes were incubated for five hours with three clear bottles and two dark bottles. The Winkler method (Strickland & Parsons 1972, Gocke 1986) was used to determine oxygen content. To convert data from ml of oxygen to mg of carbon, a photosynthetic coefficient of 1.20 was used, along with a respiration coefficient of 0.83 (Gocke *et al.* 1990). During the months of January, August, and September of 1991, and July of 1992, primary productivity was measured at the surface (I≐100%) of the sampling point located in the main channel (A). In accordance with data from these months on the average difference between the primary productivity at the surface and the following depth (I=50%), a value was calculated to estimate primary productivity at I=100% for the rest of the months, in order to integrate it within the water column. Net water column primary productivity in the main channel (A) presented values ranging between 0.69 g C/m^2 d (November 1990) and 2.53 g C/m^2 d (August 1991), with an average of 1.20 ± 0.70 g C/m^2 d. Increased production was noted in August and November of 1991 (Table 1). There was a significant difference between the dry and rainy seasons with respect to net primary productivity (z=2.196, p<0.03), with the highest average occurring in the dry season (dry season: 1.44 g C/m^2 d; rainy season: 0.99 g C/m^2 d). To calculate these values, average amount of primary productivity per month was used. The fact that the highest average values of primary productivity were observed in the dry season makes this research area a different estuary when compared with others in the tropical zone. In the majority of studies on tropical estuaries, the highest values of primary productivity have been noted during the rainy season (Sorokin 1991.) A significant difference was determined between the depths I=50% and I=10% in terms of net primary productivity (z= -2.51, p<0.006), with average values of 0.11 and 0.08g C/m^3 hr (or 1.32 and 0.96 g C/m^3 d, respectively.) Net primary productivity values obtained in Estero Morales and the Cortezas Islands place the Gulf of Nicoya among one of the world's most productive estuaries (Table 2), with values around 450g C/m^2 per year. These ranges are higher than those obtained in diverse tropical and subtropical zones, such as the Cariaco Gulf, in Venezuela, certain points of the tropical Atlantic and even upwelling zones (Table 2). With respect to temperate areas where productivity average range between 80 and 450g C/m^2 year, the Gulf of Nicoya possesses higher values in the majority of cases. It should be pointed out that results obtained in this study, like many of those appearing in Table 2, are higher than those documented for classic provinces proposed by Ryther (1969).

TABLE 1

Monthly primary productivity for the Estero Morales, a mangrove system in the Gulf of Nicoya, Costa Rica

Sampling month	Primary Productivity (g C/m^{2}d)
October, 1990	0.765
November, 1990	0.696
December, 1990	1.460
January, 1991	1.371
March, 1991	1.590
April, 1991	1.638
May, 1991	0.780
June, 1991	1.259
July, 1991	0.971
August, 1991	2.529
September, 1991	0.757
October, 1991	0.977
November, 1991	1.816
December, 1991	1.416

However, a large-scale comparison at the world level is not simple, given the lack of standardized methodology among the different authors of these types of studies. Generally, it is assumed they are working with gross primary productivity data, since this represents what is known in the literature as real productivity (Hall & Moll 1975) and because usually in poor productive areas, the ^{14}C method is used without distinction between net and gross productivity data. Table 2 offers a clear example of the ambiguity of criteria in this area, since productivity data included is expressed in very different units. For these reasons, this study has used values expressed as g C/m^2 d and those of net primary productivity, because they show the integration of water column productivity. Nevertheless, it is also useful to

TABLE 2

Primary productivity per day and per year in different estuarine and coastal ecosystems overseas

Region	Original REPORTED DATA	Productivity gC/m^3d	Productivity gC/m^2d	gC/m^2y	Source
Tomales Bay, USA	0.2-2.2 gC/m^2d		0.2-2.2	400	Cole 1989
	400 gC/m^2y				
Georgia Estuaries, USA	300 gC/m^2y			300	Yoder& Bishop 1985
River Neuse Estuary, USA	342.6 gC/m^2y			342.6	Mallin *et al*. 1991
Great South Bay. N.Y. USA	450 gC/m^2 y			450	Lively *et al*. 1983
Punta Banda Estuary. MEX.	3.26-86.72 mgC/m^3hr				Sosa-Ávalos *et al*.1997
Tropical Atlantic:					Gieskes *et al*. 1984
A. 21°40'N 18° W	1.92 gC/m^2d		1.92		
B. 20°N 27°W	0.87 gC/m^2d		0.87		
C. 20°N 36°W	0.75 gC/m^2d		0.75		
S.E. Arabic Sea	7.74 mgC/m^3d.	0.008			Sumitra *et al*. 1989
	Surface.				
	95.97 mgC/m^3d.	0.096			
	Column.				
Red Sea, Saudi Arabia	390 gC/m^2y			390	Shaikh *et al*. 1986
Buenaventura Lagoon, Cuba	924ml O_2/m^2d				González & Nodar, 1981
Hilutangan Channel, Phillipines	4.6-10.6 mgC/m^3d	0.005-0.011			von Bodungen *et al*. 1985
Oligotrophic waters					
Central Vietnam	20-100 mgC/m^2d			0.02-0.1	Sorokin 1991
	200-300mgC/m^3d	0.2-0.3			
Coral Reef	1-5 mgC/m^3d	0.001-0.005			
Great Australian Barrier					Revelante & Gilmartin
Internal lagoon	>10mgC/m^3hr	>0.12			1982
Outer lagoon	1.3-4.2mgC/m^3hr	0.016-0.050			
Cariaco Gulf, Venezuela	0.70 gC/m^2d		0.7		Mandelli & Ferraz de
	Upwelling				Reyes 1982
	0.43 gC/m^2d		0.43	231	
	Normal				
	231 gC/m^2y				
Tacariguá Lagoon, Venez.	30-187mgC/m^3hr	0.36-2.25			Rodriguez & Conde 1989
Maracaibo Lagoon, Venez.	46.33mgC/m^3hr	0.556			
Paranaguá Bay, Brazil	0.01-7.36mgC/m^3hr	0.0001-0.088			Brandini 1985
Open Ocean	50 gC/m^2y			50	Ryther 1969
Coastal Zones	100 gC/m^2y			100	
Upwelling Zones	300 gC/m^2y			300	
COSTA RICA					
Cortezas Islands, Gulf of Nicoya					
Red tide conditions	0.32gC/m^2hr		3.84		Gocke *et al*. 1990
Normal conditions	0.64gC/m^2hr		7.68		
Estero Morales Main Channel (A)	100 mgC/m^2hr		1.202	439	**This study**
	79 mgC/m^3hr	0.948			
Estero Morales Mouth (B)	89 mgC/m^2hr		1.068		
	79 mgC/m^3hr	0.948			
Cortezas Islands	141 mgC/m^2hr		1.689		
	70 mgC/m^3hr	0.839			

calculate productivity values in g C/m^3 d because these units are frequently employed.

It is very important to remember that annual estimates should be taken with some reservation, given that extremely exhaustive research is needed for extensive periods of time, such as one or two years (Renk *et al.* 1988). Even then, estimates can vary considerably from year to year (Boalch 1987).

A follow-up study is recommended for this area, consisting of simultaneous sampling at different points of the Gulf of Nicoya. These samples should be taken at a minimum of five different incubation depths for each sample in order to obtain more detailed information in calculating productivity by layers in water column. It is also recommended that frequency period (at least five following days) of sampling be increased for greater assurance that results are not produced by the distribution of patches of phytoplankton.

RESUMEN

Durante 15 meses (1990-1991) se hizo determinaciones de la productividad primaria en el estero de Morales, Golfo de Nicoya, costa Pacifica de Costa Rica. Se incubó cinco botellas DBO (Tres claras y dos oscuras) a profundidades correspondientes a un 50 y un 10 % de la luz incidente y se determinó el contenido de oxígeno mediante el método de Winkler. La productividad primaria neta en el estero Morales tuvo un promedio de 1.20 - 0.70 gC/ m^2 por día (cerca de 450 gC/ m^2 por año). Mediciones hechas en un sitio cercano (Islas Cortezas) produjeron 1.69 gC/m^2 por día. Se encontró diferencias significativas en la productividad primaria neta entre las estaciones seca y lluviosa típicas de la región del Golfo de Nicoya. Los valores de productividad permiten colocar al Golfo de Nicoya como uno de los estuarios mas productivos del mundo. Sin embargo, se recomienda un estudio más detallado (mayor número de sitios, profundidades y mediciones).

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