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SESSILE CILIATES ON ARTIFICIAL SUBSTRATA SUBMERGED IN A POLLUTED ESTUARY (SANTOS, SP, BRAZIL)

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Synopsis

Primary growth was analysed on artificial substrata submerged at three sites of the Santos estuary (State of São Paulo, Brazil). Research on sessile ciliates was emphasized because they were the most conspicuous organisms of the primary growth developed along this estuary. Zoothamnium commune *dominated near the headwaters of the estuary, where the greatest amount of suspended matter in the water was found.* Ephelota gemmipara *dominated downstream. Although short time variability was observed in the colonization of substrata submerged on subsequent days, seasonal patterns could be determined. These patterns were characterized by a greater number of rare species of sessile ciliates, and a higher density of the most frequent ones, during spring and summer.*

Descriptors: Periphyton, Artificial substrata, Estuaries, Pollution, Sessile ciliates, Ciliata, Santos-SP, Southern Brazilian coast.
Descritores: Perifiton, Substratos artificiais, Estuários, Poluição, Ciliados sésseis, Ciliata, Santos-SP, Costa sul-Brasil.

Introduction

Associations of protozoa or diatoms have been used by several authors to define a polluted environment, since the abundance and composition of these organisms may change quickly according to water quality (Patrick *et al.*, 1954; Heulekian & Crosby, 1956; Genovese & Gangemi, 1966; Burbank & Spoon, 1967; Persoone, 1968; Wilbert, 1969; Parrish & Lucas, 1970; Relini *et al.*, 1976; Cairns Jr *et al.*, 1978; Henebry & Cairns Jr, 1980; Marcus, 1980). The primary colonizers of substrata, either natural or artificial surfaces, are protozoa, diatoms, bacteria, and eventually macroscopic organisms (Persoone 1968; 1971). Artificial substrata have been used for quantitative studies and for comparisons of the primary growth between environments, since natural surfaces are irregular, rugose, and not favorable for quantitative analysis (Sládecková, 1962).

In the present paper, sessile ciliates were studied to determine changes in the community structure with distance from pollution sources as well as temporal variation, since they are the most conspicuous organisms of the primary growth developed in the Santos estuary.

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Material and methods

Study site

Santos estuary is placed at southern Brazilian coast (23°56'S - 46°20'W) (Fig. 1). It is a coastal plain estuary which receives coarse sediments carried by the rivers descending from "Serra do Mar" mountains (Goldenstein, 1972). The fluvial system is the main source of the existing pollution: the estuary receives urban and industrial effluents, presenting a decreasing gradient of nitrate, phosphate, mercury, pesticides, and sediments in suspension in the water from the headwaters downstream (Tommasi, 1979).

Methods

Three collection sites positioned in a transect along the estuary were chosen (Fig. 1). Samples were obtained every 45-60 days from May 1979 to March 1980 at all three sites. An experiment related to short time variability was made at site C in January 1980, for 8 consecutive days. Microscope cover slips (22 x 22 mm), used as surfaces for colonization, were maintained in a vertical position fastened by acrylic supports. These supports were placed 0.5 m deep in the water anchored to local piers, where they remained for 5 days. Pairs of cover slips were held together in order to avoid colonization on both sides. Immersion time was previously determined in order to sample a community that represented the primary growth. Once removed from the water, four replicas of cover slips of each collecting site were fixed with Bouin and stained using the Protargol technique, following the methodology modified by Eugene B. Small (Laboratory notes in protozoology, Fall 1976, Dept. Zoology, Univ. Maryland, MD, U.S.A.).

Fig. 1 - Santos estuary, with position of collection sites (A, B and C).

Ten percent of the surface of the cover slips was established as the minimum area necessary to quantify the sessile species with random distribution, sampled in random plots of 1 mm^2. Rare species or species with gregarious distribution were counted on the total area of the cover slips. Since points of fixation of the organisms to the substrata were counted, the number of individuals of colonial species is underestimated. Vagile ciliates were not quantified. Morisita's similarity coefficient Cλ (Grassle & Smith, 1976) was calculated between samples, and the results were clustered by the weighted pair-group method using arithmetic averages (Davis, 1973; Sneath & Sokal, 1973).

Measurements of salinity, temperature, transparency, dissolved oxygen, suspended matter (inorganic and organic), chlorophyll-*a* and pheophytin-*a* of the water were estimated at the collection sites by the time of placement of the substrata and a fortnight later. Duplicate samples of the last four parameters were averaged. Indexes of rainfall were obtained from Instituto Nacional de Meteorologia (7º distrito), Ministério da Agricultura.

Results

Ciliates

Two types of association were formed by the sessile ciliates in the Santos estuary: 1) the primary growth at sampling site A, where *Zoothamnium commune* dominated; 2) primary growth at sites B and C, where *Ephelota gemmipara* predominated. The dominance, either of *Z. commune* or of *E. gemmipara*, was responsable for setting apart site A from sampling sites B and C when data were clustered (Figs 2-3).

Zoothamnium commune was found on all substrata submerged at the three collecting sites. It was the dominant species at site A, followed by *Zoothamnium* sp (sensu Kahl, 1935) (Table 1). At site B *Z. commune* also occurred in great numbers although in rather less amount than *Ephelota gemmipara* (Table 2). Small colonies of *Zoothamnium* were more commonly found than large ones, and a decrease in the size of the colonies towards the mouth of the estuary was observed. Few large colonies of these species, with 500 to 1000 zooids, were observed during October and December of 1979 at site A. At site B the bigger colonies had 250 individuals (December of 1979) while at site C the maximum number of zooids per colony was 50 (December of 1979).

Ephelota gemmipara was the dominant species in almost every sample obtained at sites B and C (Tables 2-3). Encysted individuals predominated over non encysted ones in about 50% of the substrata submerged at these two places. At site A only 4 individuals of this species were observed during the sampling period, all encysted (Table 1). Some of the cysts were found parasitezed; parasitism of *E. gemmipara* by *Hypocoma* sp was observed in May, December, January, and March at sampling sites B and C, periods of great abundance of *E. gemmipara*.

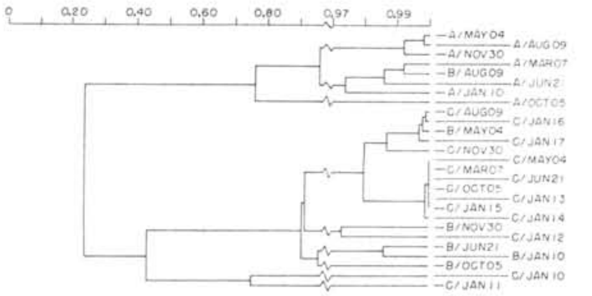

Fig. 2 - Results of the cluster analysis between substrata submerged at the collection sites in different periods of the year. Data of the replicate samples were gathered. Date of submersion of the substrata is indicated.

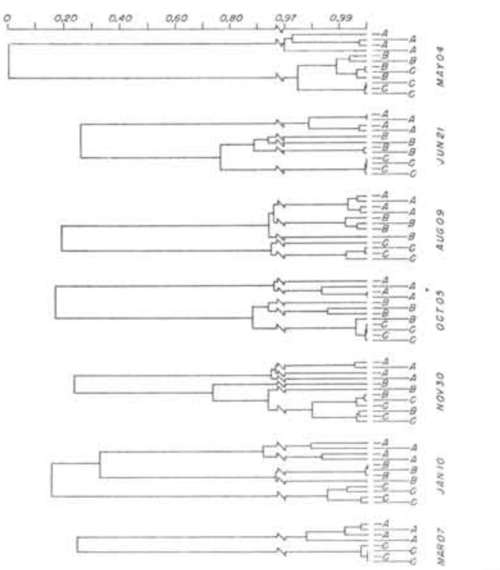

Fig. 3 - Results of the replicate samples of the substrata submerged at the collection sites clustered by the time of the year. Date of submersion of the substrate is indicated.

In the short time variability experiment *Acineta tuberosa* dominated followed by *Z. commune* in great numbers on the cover slips submerged on January 10 and 11 at site C. From January 11 onwards, the numbers of *E. gemmipara* started to increase while *Z. commune* decreased. From January 12 on, the number of *A. tuberosa* decreased as well while *E. gemmipara* became dominant (Table 4).

High densities of sessile ciliates and a greater number of rare species were observed during spring and summer. The heavier colonization periods were observed from October to March, with more than 1000 points of fixation / cm^2 (Fig. 4). In addition to *Zoothamnium commune*, both *Acineta tuberosa* and *Zoothamnium* sp. (sensu Kahl, 1935) occurred in great numbers during October at site A. In the other sampling periods only *Z. commune* was dominant at this collecting site (Table 1). *Ephelota gemmipara* shared its dominance with *A. tuberosa* during December and with *Z. commune* during January at site B, and with *A. tuberosa* and *Z. commune* during January at sampling site C (Tables 2-3). A change in the density of the sessile ciliates was observed on substrata submerged at site C on consecutive days during January of 1980 (Fig. 4B).

The greatest number of species was found during October at site B and during December at sites A and C (Fig. 5). Individuals of *Acineta* sp, *Cothurnia* sp, *Epistylis* sp, *Platycola gracilis*, *P. regularis*, *Podoprhya fixa*, *Pyxicola socialis*, *Vaginicola crystallina*, *Vorticella* sp 1 and *Vorticella* sp 2 were found only in the warmer months and in small numbers. *Cothurnia maritima* and *Vorticella nebulifera* were found in varying numbers troughout the year (Tables 1-4).

Vagile ciliates such as *Hemiophrys*, *Hypocoma*, *Thigmogaster*, *Trochilia* and some unidentified Gymnostomata, were found at all sampling sites. Herbivores, such as *Nassula* and *Chilodonella* (Fauré-Fremiet, 1961; Dragesco, 1962; Bick, 1972), were never present at sampling site A. Great numbers of certain vagile ciliates occurred occasionally although never surpassing the amount of the sessile ones: *Hemiophrys* at site A in October; *Thigmogaster* at sites A and B in May and January, and at A also in October, December and March; *Hypocoma* at sites B and C in May, and at C also in December and January; *Dileptus* at C in May; and *Chilodonella* at site C in January. Although the number of species of vagile ciliates increased towards the mouth of the estuary, predators of peritrichs, such as *Dileptus* and *Hemiophrys* (Dragesco, 1962; Curds, 1969; Small, 1973), were sporadically found in great numbers both at the headwaters and downstream.

Table 1 - Density of sessile ciliates on artificial substrata submerged at site A throughout the sampling period

Period of submersion / Species	May 04-09				Jun 21-26				Aug 23-28				Oct 05-10				Nov 30-Dec 05				Jan 10-15				Mar 07-12			
Ephelota gemmipara	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-
Podophrya fixa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acineta tuberosa	11	2	5	2	2	5	-	1	47	23	14	31	1683	1835	1025	997	251	32	46	29	80	12	28	46	305	483	652	178
Acineta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Epistylis sp	-	-	-	-	-	-	-	-	-	-	-	-	1	2	4	2	-	1	2	-	4	-	1	2	28	87	45	20
Vorticella nebulifera	11	2	12	-	-	-	-	1	10	10	33	4	135	22	6	-	31	30	-	12	32	1	2	3	602	327	218	33
Vorticella sp 1	-	-	-	-	6	8	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	1	2	-	-	-	-
Vorticella sp 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella sp 3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-
Zoothamnium commune	176	154	113	92	68	84	74	118	394	439	528	545	3480	2530	2570	2410	2680	1710	2752	2162	417	345	287	379	4670	5200	3100	3690
Zoothamnium sp	37	70	54	31	-	-	-	-	119	170	130	136	2073	2870	2770	2520	350	700	520	620	14	3	9	46	9	8	95	131
Cothurnia maritima	2	-	-	21	17	6	17	4	14	20	16	48	123	42	63	47	165	168	168	773	192	32	90	3	90	127	112	42
Cothurnia sp	1	2	1	2	-	-	-	-	-	-	-	-	7	7	16	24	3	11	16	6	-	-	-	-	-	-	-	5
Platycola gracilis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	7
Platycola regularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyxicola socialis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	-	4	-	-	-	-	-	-	-
Vaginicola crystallina	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	5	2	-	-	-	-	-	-	-	-
Total density (N)	239	230	186	149	93	103	96	124	584	663	721	764	7502	7308	6467	6001	3482	2654	3512	3606	743	397	419	482	5705	6232	4222	4106
N/cm²	54	52	42	34	21	23	22	28	133	151	164	174	1705	1661	1470	1364	791	603	878	819	169	90	95	109	1297	1416	959	933

Table 2 - Density of sessile ciliates on artificial substrata submerged at site B throughout the sampling period.

Period of submersion / Species	May 04-09				Jun 21-26				Aug 23-28			
Ephelota gemmipara	1290	2200	3700	1761	404	653	318	285	48	-	-	13
Podophrya fixa	-	-	-	-	-	-	-	-	-	-	-	-
Acineta tuberosa	3	2	8	6	17	4	46	67	13	6	2	-
Acineta sp	-	-	-	-	-	-	-	-	-	-	-	-
Epistylis sp	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella nebulifera	12	32	25	95	25	1	21	17	11	40	42	127
Vorticella sp 1	58	19	14	16	2	-	-	-	-	-	-	-
Vorticella sp 2	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella sp 3	1	-	-	-	-	-	-	-	-	-	-	-
Zoothamnium commune	152	472	360	134	187	196	271	321	474	452	497	364
Zoothamnium sp	88	28	48	36	-	-	-	-	25	54	24	17
Cothurnia maritima	91	144	74	62	104	18	10	19	18	11	19	8
Cothurnia sp	-	-	1	1	-	-	-	1	-	2	-	-
Platycola gracilis	-	-	-	-	-	-	-	-	-	-	-	-
Platycola regularis	-	-	-	-	-	-	-	-	-	-	-	-
Pyxicola socialis	-	-	-	-	-	-	-	-	-	-	-	-
Vaginicola crystallina	-	-	-	-	-	-	-	-	-	-	-	-
Total density (N)	1695	2897	4230	2111	739	872	666	710	589	565	584	529
N/cm^2	385	658	961	480	168	198	151	161	134	128	133	120

Period of submersion / Species	Oct 05-10				Nov 30-Dec 05				Jan 10-15			
Ephelota gemmipara	4040	4880	3020	3830	2180	2540	4150	3070	4830	4620	3370	2550
Podophrya fixa	1	-	-	-	4	5	-	-	-	-	-	-
Acineta tuberosa	244	187	258	301	2412	181	302	806	7	25	23	63
Acineta sp	-	-	-	-	-	-	-	-	-	-	-	-
Epistylis sp	6	2	3	4	-	-	-	-	-	-	3	-
Vorticella nebulifera	16	10	182	19	4	2	18	12	366	448	351	126
Vorticella sp 1	3	-	2	-	55	-	-	1	6	7	13	-
Vorticella sp 2	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella sp 3	-	-	1	-	-	-	-	-	-	-	-	-
Zoothamnium commune	921	78	1479	1311	822	1066	319	351	2560	1020	1370	1380
Zoothamnium sp	1303	102	38	70	-	-	1	-	-	-	-	-
Cothurnia maritima	42	145	131	24	15	20	11	8	85	827	130	186
Cothurnia sp	1	-	1	1	1	-	1	-	-	-	-	-
Platycola gracilis	-	-	-	-	-	-	-	1	-	-	-	-
Platycola regularis	-	-	-	-	-	-	-	-	-	-	-	-
Pyxicola socialis	1	-	-	-	-	1	-	-	-	-	-	-
Vaginicola crystallina	5	-	2	-	71	25	1	9	64	75	26	67
Total density (N)	6583	5404	5117	5560	5564	3840	4803	4258	7918	7022	5286	4372
N/cm^2	1496	1228	1163	1264	1254	873	1092	968	1799	1596	1201	994

Table 3 - Density of sessile ciliates on artificial substrata submerged at site C throughout the sampling period

Period of submersion / Species	May 04-09				Jun 21-26				Aug 23-28				Oct 05-10				Nov 30-Dec 05				Jan 10-15				Mar 07-12			
Ephelota gemmipara	2880	1944	1910	880	916	3376	1850	1067	302	103	83	96	13320	8390	6500	9660	3830	2310	2560	2590	5	9	9	12	2320	4156	7161	3873
Podophrya fixa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acineta tuberosa	3	2	4	7	-	1	1	23	-	-	-	1	13	20	41	13	289	590	243	510	4185	2460	4704	3126	109	3	-	17
Acineta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epistylis sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella nebulifera	5	3	2	-	-	-	-	2	-	-	1	4	4	3	9	2	48	169	56	97	21	17	26	49	16	35	25	30
Vorticella sp 1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	-	-	-	-	-	-	-	-
Vorticella sp 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella sp 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zoothamnium commune	11	16	21	90	21	24	14	21	15	36	31	22	70	125	169	181	162	257	286	203	1110	410	380	380	66	41	115	64
Zoothamnium sp	-	-	-	-	-	-	-	-	-	-	-	-	3	6	4	5	4	-	1	1	-	-	-	-	-	-	-	-
Cothurnia maritima	-	1	17	-	-	-	-	3	2	1	8	-	1	-	5	11	5	6	9	63	13	208	11	41	-	-	-	-
Cothurnia sp	1	45	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-
Platycola gracilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Platycola regularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	8	-	-	-	-
Pyxicola socialis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Vaginicola crystallina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
Total density (N)	2900	2012	1954	977	937	3401	1865	1116	319	140	123	123	13411	8544	6735	9873	4340	3334	3158	3472	5336	3104	5130	3616	2511	4235	7301	3985
N/cm²	659	457	444	222	213	773	424	254	72	32	28	28	3048	1942	1531	2244	986	758	718	789	1213	705	1166	822	571	962	1659	906

Table 4 - Density of sessile ciliates on artificial substrata submerged in January of 1980 at site C for 8 consecutive days

Period of submersion / Species	Jan 10-15				Jan 11-16				Jan 12-17				Jan 13-18				Jan 14-19				Jan 15-20				Jan 16-21				Jan 17-22			
Ephelota gemmipara	5	9	9	12	3540	2180	6300	3222	5100	6320	5000	11880	14500	11160	14520	13240	7960	3700	1400	1760	5340	3520	3690	6650	4490	1630	163	899	1221	1968	3437	1105
Podophrya fixa	-	-	-	-	6	2	25	14	3	11	3	4	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-
Acineta tuberosa	4185	2460	4704	3126	7606	3191	2238	5519	3621	2940	3050	3500	201	156	431	292	155	17	180	25	74	52	10	54	1	-	-	9	2	67	15	L
Acineta sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epistylis sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella nebulifera	21	17	26	49	68	102	26	136	31	96	65	61	13	11	6	7	-	3	11	5	5	58	5	25	148	3	1	23	27	26	21	205
Vorticella sp 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Vorticella sp 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vorticella sp 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zoothamnium commune	1110	410	380	380	459	300	732	376	159	337	58	161	114	50	78	38	77	62	97	116	98	283	195	185	183	249	369	197	94	135	242	218
Zoothamnium sp	-	-	-	-	3	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cothurnia maritima	13	208	11	41	1	7	5	-	-	9	1	1	1	10	1	1	2	34	15	1	-	9	20	1	2	17	39	5	-	-	38	9
Cothurnia sp	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	2	-	-	-	-	6	27	1	2
Platycola gracilis	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	-	-	-	-	-	-
Platycola regularis	2	-	-	8	-	1	2	1	3	1	-	-	2	-	-	-	-	1	2	-	4	10	8	8	2	2	6	12	40	13	21	6
Pyxicola socialis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Vaginicola crystallina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	7	-	-	-	-	-
Total density (N)	5336	3104	5130	3616	11683	5785	9330	9268	8918	9714	8177	15607	14831	11388	15036	13579	8194	3817	1705	1908	5521	3936	3929	6925	4831	1907	586	1146	1390	2236	3777	1554
N/cm^2	1213	705	1166	822	2655	1315	2120	2106	2027	2208	1858	3547	3371	2588	3417	3086	1862	867	387	434	1255	894	893	1574	1098	433	133	260	316	508	858	353

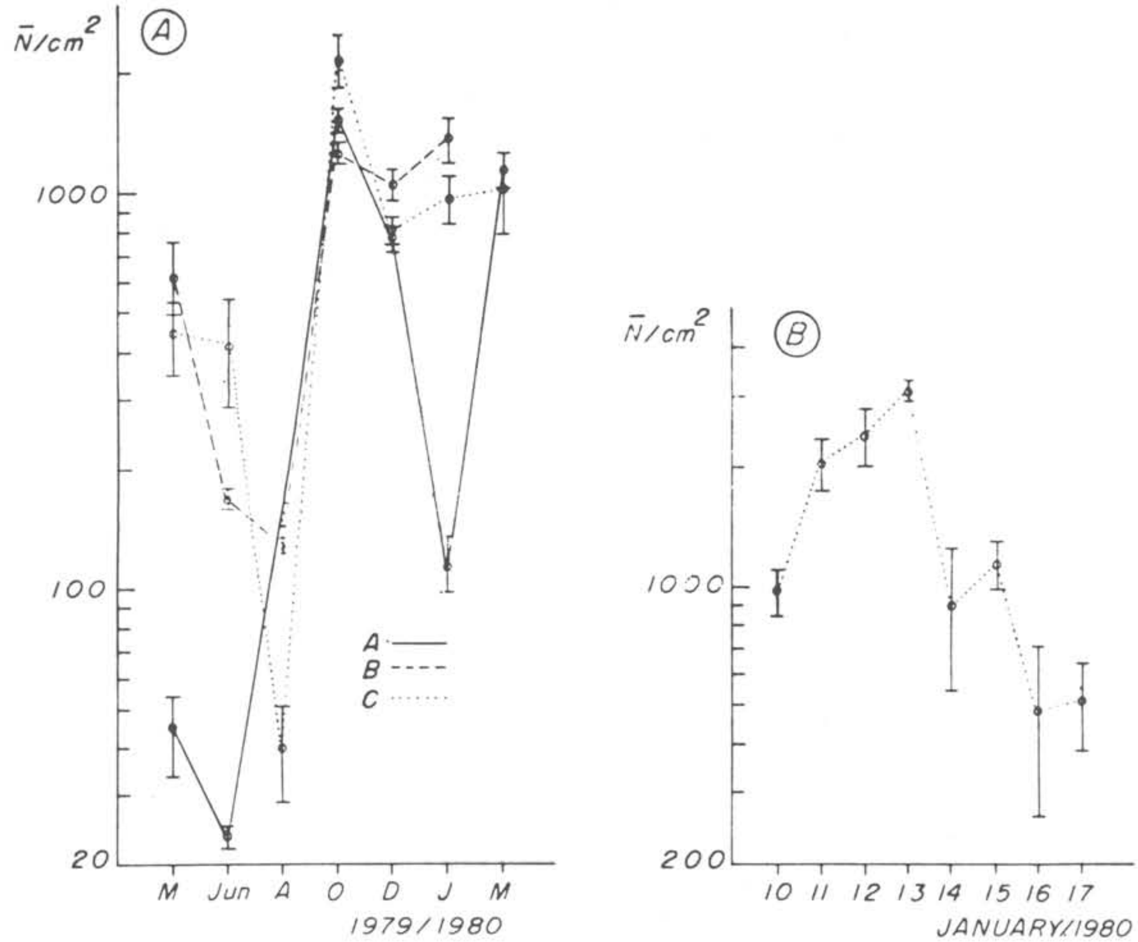

Fig. 4 - Mean number of points of fixation of the sessile ciliates by substratum area ($\bar{N}/cm^2$). Bars indicate standard deviation of the mean. A) Seasonal variability at the sampling sites; B) Daily variability at site C of collection. Date of submersion of the substrata is indicated.

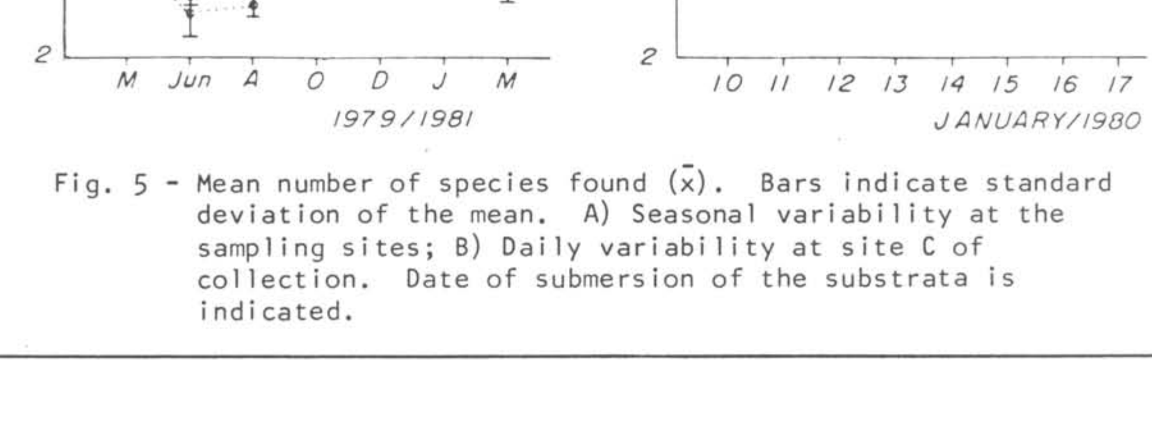

Fig. 5 - Mean number of species found ($\bar{x}$). Bars indicate standard deviation of the mean. A) Seasonal variability at the sampling sites; B) Daily variability at site C of collection. Date of submersion of the substrata is indicated.

Environmental factors

Temperature of the water presented a seasonal pattern, with maximum values during summer (November to March), from 24 to 29°C, and minimum values during winter (June to August), from 19 to 22°C (Fig. 6). Annual fluctuations of temperature were about 10°C. An oscillation of 5°C was observed in the daily samples obtained during January of 1980 at collection site C. Salinity varied from 1.6 to 12.1 °/oo at collecting site A, from 3.7 to 22,1 °/oo at site B and from 4.1 to 23.4 °/oo at site C. During the short time variability experiment, salinity values at site C varied from 4.1 to 21.4 °/oo (Fig. 6). Minimum rainfall indexes were registered in June and August while the maximum one was attained in November (Table 5).

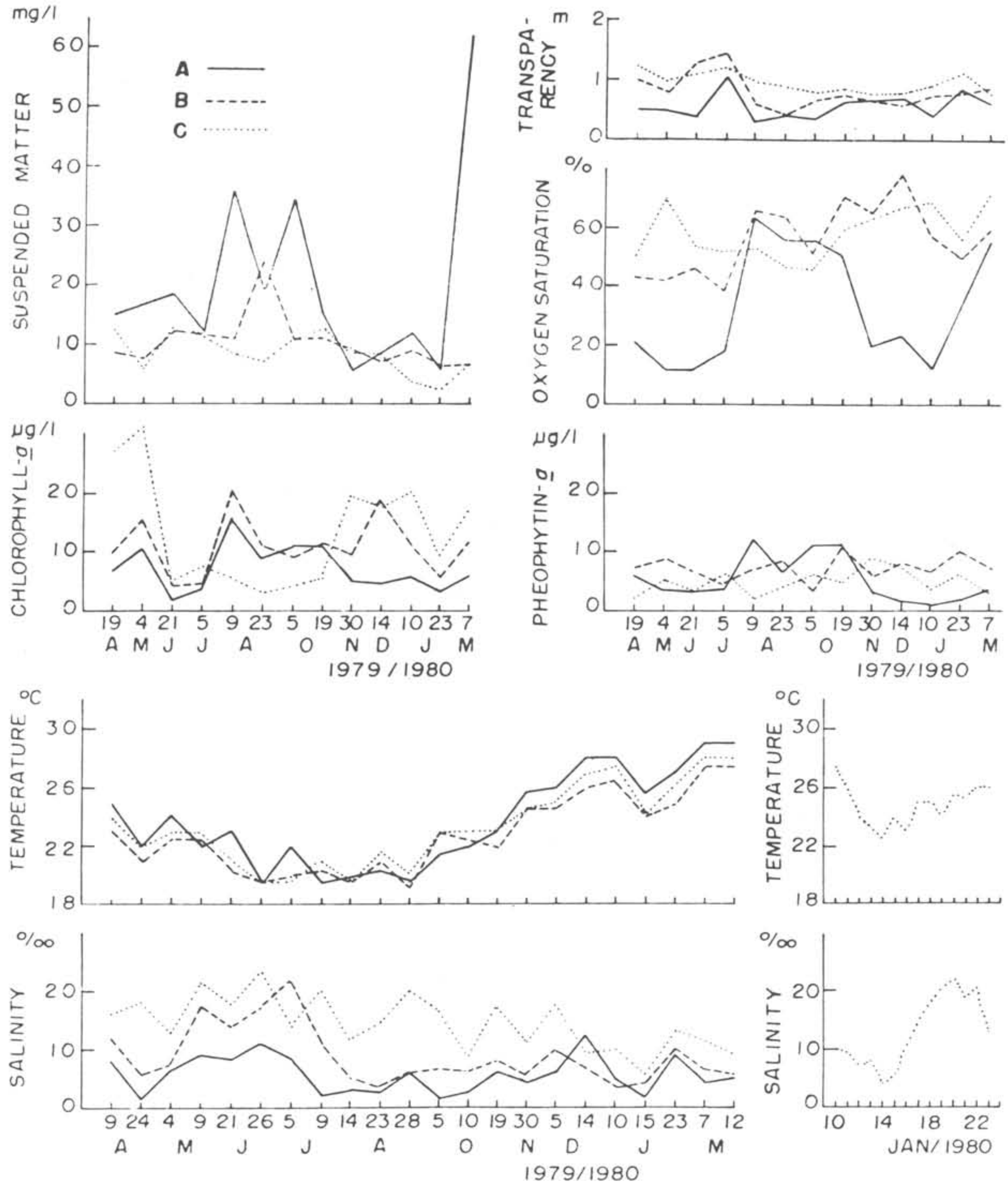

Fig. 6 - Environmental data at collection sites.

Table 5 - Monthly indexes of rainfall (data granted from Instituto Nacional de Meterorologia - 7º distrito - Ministério da Agricultura)

Date	Indexes of rainfall (mm)
May 1979	103.7
Jun	56.1
Jul	159.3
Aug	57.8
Sep	234.7
Oct	147.0
Nov	314.4
Dec	256.6
Jan 1980	255.7
Feb	294.4
Mar	260.3

The amount of suspended matter decreased from the headwaters to the mouth of the estuary (Fig. 6). Inorganic matter represented the bulk of the suspended matter, and varied from 4.7 to 57.1 mg/l at site A, from 4.9 to 20.2 mg/l at site B and from 0.7 to 11.7 mg/l at site C. Concentrations of insoluble organic matter amounts varied between 0.1 and 7.2 mg/l at site A, between 0.9 and 4.6 mg/l at site B and between 0.5 and 6.3 mg/l at site C (Table 6). Transparency of the water was low (Fig. 6), an inverse relationship being noticed between transparency of the water and the amount of suspended matter present at the three sample sites.

Dissolved oxygen was always below saturation levels (Fig. 6), the lowest and most variable values observed at site A (11.68 to 62.97 %). Percent saturation from 37.65 to 78.02 % were determined at site B, and from 46.04 to 71.58% at site C. Chlorophyll-*a* concentrations varied from 1.89 to 16.57 µg/l at site A, from 4.15 to 19.82 µg/l at site B and from 2.67 to 31.13 µg/l at site C (Fig. 6). Amounts of pheophytin-*a* varied from 0.73 to 12.24 µg/l at site A, from 2.97 to 10.52 µg/l at site B and from 2.02 to 8.97 µg/l at site C (Fig. 6) denoting the presence of unhealthy or dead phytoplankton cells in the samples.

Discussion

Ciliates are tolerant with respect to several environmental factors (Corliss, 1973). Salinitity and temperature, usually the most important features determining the distribution of marine animals, are not as significant for the distribution of benthonic marine ciliates (Webb, 1956; Fenchel, 1969; Borror, 1975; Wilbert & Kahan, 1981). Occurrence and local abundance of the species of ciliates are related to the type of available food (Noland, 1925 *cit. in*: Taylor & Berger, 1976; Webb, 1956; Reid, 1969; Wilbert, 1969; Borror, 1975; Taylor, 1978) and to oxygen concentration (Stout, 1956; Taylor, 1979). At low levels of oxygen, number and amount of the aerobic species are reduced, even when abundant food reserves seem to be available (Wilbert, 1969; Bick, 1973).

The quicker colonization of the substrata by *Zoothamnium* colonies towards the headwaters of the estuary may be indirectly related to increasing amount of suspended matter. Peritrichous ciliates feed essentially on bacteria and when abundant they indicate an organically polluted environment (Parrish & Lucas, 1970; Bick, 1973; Finley, 1974; Henebry & Ridgeway, 1979). Bastida (1968) considers *Z. commune* an indicator of polluted waters since, in harbors, it increases in number with raising contamination. *Z. commune* was also the most frequent species observed on the primary growth of an internal place of the harbor at Genoa, Italy, polluted by urban wastes (Relini *et al.*, 1976), and it was observed by Persoone (1968) in the harbor of Ostend, Belgium, a polysaprobic estuary.

The unexpected low numbers of *Z. commune* in the January samples of site A seem to be related to low percentage of oxygen saturation (Fig. 6), instead of little amount of organic matter available, which was not the case (Table 6). Also during May and June, other periods of very low oxygen saturation levels at this sampling site, the density of *Zoothamnium commune* was low.

Vagile ciliates can not be responsible for the decreasing amount of *Z. commune* down the estuary for predators of peritrichs were sporadically found in great numbers, both at headwaters and

Table 6 - Inorganic and organic fraction of the suspended matter (mg/l)

Date \ Sampling site	A		B		C	
	inorganic matter	organic matter	inorganic matter	organic matter	inorganic matter	organic matter
Apr 19, 1979	9.8	5.0	5.5	2.9	6.0	6.3
Jun 21	11.2	7.2	7.6	4.3	7.5	4.8
Jul 05	8.4	3.4	6.9	4.6	5.3	6.1
Aug 09	32.4	3.6	8.0	2.6	8.1	0.5
Aug 23	16.5	2.7	20.2	3.8	6.2	1.0
Oct 05	29.3	4.6	9.6	1.6	9.4	1.0
Oct 19	11.2	3.6	8.5	2.7	11.7	0.9
Nov 30	5.3	0.1	8.0	1.1	6.0	2.5
Dec 14	6.5	2.3	4.9	2.8	4.4	3.8
Jan 10, 1980	7.3	4.8	4.9	3.9	0.7	2.8
Jan 23	4.7	0.6	5.1	1.0	1.7	0.7
Mar 07	57.1	6.1	5.8	0.9	5.7	0.8

downstream. Also immigration was not being prevented since there was still space available for colonization when cover slips were removed from the water (Eston, 1981).

Decrease in the *Acineta tuberosa* numbers on consecutive days in the January samples of site C seems to be related to the reestablishment of the *E. gemmipara* population. As they are both carnivorous species (Grell, 1973), competition for food between them or mutual predation on young stages shoud be investigated in order to understand their replacement on the cover slips.

Although short time variability was observed in the colonization of substrata submerged on subsequent days, seasonal patterns could be determined. They were characterized by higher densities of sessile ciliates and a greater number of the rare species during spring and summer. Increase in the mobility and reproductive rate during the warmer periods (see Schoener, 1974) was certainly responsible for the seasonal patterns observed. On the other hand, the local variability observed among replicate samples was probably caused by random colonization of the organisms (see Sutherland & Karlson, 1977).

Conclusion

The two types of association formed by the sessile ciliates denote the existence of different environmental conditions along the estuary of Santos. Shift in the dominance from *Ephelota gemmipara* to *Zoothamnium commune* towards the headwaters of this estuary seemed to be related to increasing amount of suspended matter in the water, whenever oxygen concentration levels were not extremely low.

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