NUTRIENT AND CHLOROPHYLL *A* DISTRIBUTION IN RELATION TO WATER COLUMN STRUCTURE IN THE MALI STON BAY (SOUTHERN ADRIATIC)

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Sampling was performed once a month at Usko station (12 m max. depth) in the Bay of Mali Ston from February 88 to February 89. The Bay of Mali Ston is an unpolluted area favouring oyster and mussel farming. This area is influenced by the fresh water income from the Neretva river at the outher part and submarine springs in the inner part. Parameters were determined by standard oceanographic methods (STRICKLAND and PARSONS, 1972).

The aim of this work has been to describe the distribution of nutrients and chlorophyll *a*, as well as their respective correlation to hydrodynamic characteristics of the water column. According to these hydrodynamic characteristics of the water column recorded throughout the year, two different periods were observed to exist : mixing (October-April) and stratification (May-September). During the stratification period, water column was divided into three layers: above, at and below pycnocline depth. The data on ranges, means and standard deviations of parameters investigated for annual, mixing and stratification periods are presented in Table 1. During the stratification period, all the parameters, except ammonia and reactive silicate, had the lowest range, mean and standard deviation. As regards the parameters above, at and below pycnocline, maximum values, excepting ammonia, were found above pycnocline depth. Significant difference between the layers was found only in nitrate and reactive phosphorus (Table 2).

Table 1. Range, mean, standard deviation (SD) of nutrients and chlorophyll *a* in annual, mixing and stratification periods.

	Annual (n=83)			Mixing (n=49)			Stratification (n=34)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
c (NO_3)	0.96	1.54	0.01-9.73	1.28	1.90	0.06-9.73	0.53	0.65	0.00-2.52
c (NO_2)	0.14	0.22	0.01-1.11	0.21	0.27	0.01-1.11	0.04	0.03	0.01-0.13
c (NH_4)	0.72	0.84	0.01-3.98	0.62	0.60	0.05-2.20	0.86	0.89	0.01-3.98
c (TIN)	1.82	1.82	0.14-10.70	2.10	2.12	0.17-10.70	1.43	1.24	0.14-5.02
c (PO_4)	0.09	0.06	0.01-0.33	0.09	0.06	0.01-0.33	0.08	0.05	0.03-0.29
c (SiO_4)	2.92	1.77	0.21-7.15	3.16	1.70	0.21-6.18	2.59	1.85	0.37-7.15
φ O_2/O_2'	1.09	0.10	0.86-1.32	1.03	0.08	0.86-1.32	1.18	0.05	1.06-1.29
Chl *a*	1.44	1.54	0.21-6.73	1.94	1.84	0.25-6.73	0.77	0.37	0.21-1.58

c- μmol dm^{-3}, chl a - μg dm^{-3}

Table 2. The means of nutrients and chlorophyll *a* in pycnocline layers.

Layers	NO_3	NO_2	NH_4	TIN	PO_4	SiO_4	O_2/O_2'	Chl *a*
Above	1.10^{a*}	0.05	0.78	1.94	$0.11^{a,a*}$	3.46	1.20	0.86
At	0.39^{b*}	0.03	0.71	1.13	$0.05^{b,b*}$	2.22	1.19	0.73
Below	0.20^{b*}	0.04	0.94	1.19	0.08^{c}	2.34	1.16	0.73

*The means in the same column followed by different superscript are significantly different P<0.05, with * P<0.01 (ANOVA, SNK-multiple range test).*

A simple correlation coefficient, both negative and positive, was found among chlorophyll *a* and nutrients (Table 3). The correlation was not established to exist on an annual basis, except for nitrite. Chlorophyll *a* was significantly correlated to ammonia, total inorganic nitrogen ($P<0.001$), nitrite, reactive silicate ($P<0.01$) and reactive phosphorus ($P<0.05$) during the stratification period. During the mixing period, chlorophyll *a* significantly correlated only with reactive silicate ($P<0.001$). During the stratification period (at different levels), chlorophyll *a* significantly depended upon reactive silicate, ammonia and total inorganic nitrogen above pycnocline depth, with nitrite, ammonia, total inorganic nitrogen and reactive phosphorus ($P<0.01$) below pycnocline depth (Table 4). At pycnocline depth, the depedence was not established.

An intensive development of phytoplankton preceding the stratification period caused a decrease in concentration of most nutrients. An increase in reactive silicate concentration was caused by a haline stratification, namely, a fresh water influx, while high ammonia concentration recorded throughout the water column and especially below the pycnocline is indicative of a high heterotrophic activity. Most significant correlations between chlorophyll *a* and nutrients were found during the stratification period, especially below pycnocline depth.

Table 3. Simple correlation coefficients between chlorophyll *a* and nutrients for annual data (A),mixing (M) and stratification (S) periods.

		NO_3	NO_2	NH_4	TIN	PO_4	SiO_4
	A	0.033	0.299*	0.066	0.172	0.207	-0.182
Chl *a*	M	-0.215	0.175	0.179	-0.030	0.195	-0.522***
	S	0.229	0.537**	0.631***	0.583***	0.401*	0.539**

* P<0.05, ** P<0.01, *** P<0.001.

Table 4. Simple correlation coefficients between chlorophyll *a* and nutrients in three layers during stratification period.

		NO_3	NO_2	NH_4	TIN	PO_4	SiO_4
	Above	0.442	0.486	0.612*	0.642*	0.377	0.866***
Chl *a*	At	-0.308	0.058	0.552	0.404	-0.107	0.152
	Below	0.078	0.599**	0.684**	0.677**	0.607**	0.190

* P<0.05, ** P<0.01, *** P<0.001.

REFERENCE

STRICKLAND J. D. H. and PARSONS T. R., 1972. A practical handbook of seawater analysis. *Bull. Fish. Res. Bd. Can.*, 167 : 310 p.

DIEL MESOZOOPLANKTON ACTIVITY IN AN OLIGOTROPHIC STATION OF NW MEDITERRANEAN: POSSIBLE IMPLICATIONS ON THE MICROBIAL LOOP

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The diel migration of zooplankton is an extensively studied phenomenon. Other zooplankton activities such as ingestion of food (DAGG & GRILL, 1980) and the activity of digestive enzymes (BOUCHER & SAMAIN, 1974) may also show a diel variation. In this study (1) the coupling between the diel variations of nutrition and migration of the zooplankton (2) the possible effect of the zooplankton migration on planktonic microorganisms (pico and nanoplankton i.e., bacteria and nanoflagellates) were examined. For this purpose a diel cycle of sampling was undertaken on a fixed oceanic station (43° 02 N, 05° 12 E, 1000 m depth) in June 1993.

The biological parameters measured included chlorophyll *a*, concentration of bacteria, phototrophic and heterotrophic nanoflagellates, ciliates and mesozooplankton. Water samples were collected at three hour intervals over a 24 h period from 5 and 40 m depths. Mesozooplankton samples were collected by vertical hauls (50-0 m, WP2 net). Triplicate zooplankton samples (mainly copepods, 81%) were incubated during 24 h, in filtered seawater (0.2 μm). Dissolved oxygen (polarographic electrode) and ammonia (colorimetric method) were measured at the end of the experiment and the atomic ratio O:N (oxygen consumption through respiration, relative to nitrogen excretion) was calculated (OMORI & IKEDA, 1984). The gut fluorescence (from acetone extracts of zooplankton), digestive enzymes, amylase (STREET & CLOSE, 1956) and trypsin (ERLANGER *et al.*, 1961) were measured from subsamples of zooplankton stored in liquid nitrogen within a week of sampling. Bacterial production was measured by the [^{3}H]thymidine method. Copepods numerically dominated (71%) the zooplankton population. Four copepod genera -*Clausocalanus* spp., *Paracalanus* spp., *Oithona* spp. and *Centropages* sp. prevailed in the copepod community. Appendicularians (12%) and Cladocerans (13%) were also recorded. The abundance of zooplankton was higher in the surface layer (50-0 m) during the night hours than during the day (min. 454 ind.m^{-3} at 15h00, max 1490 ind.m^{-3} at 24h00, (Fig. 1). The effect of zooplankton migration on chlorohyll concentration and on organims that could potentially be used as prey (e.g. nanoflagellates) was not clear. In fact no significant differences (Mann-Whitney test) were found between day and night samples. Microscopic examination showed that, organisms less than 7 μm prevailed in the nanoflagellate population; moreover chlorophyll size fractionation revealed that about 70% of phytoplankton was < 10 μm. These observations could suggest that copepods preferred to graze upon bigger organisms (large flagellates, phytoplankton and ciliates). Significant differences in bacterial numbers were found between night and day samples (Mann-Whitney test t=2, p= 0.005). Bacteria can adapt quickly to nutritional resources (bottom-up control), especially in oligotrophic conditions (PEDUZZI & HERNDL, 1992). The increase of bacteria production in evening hours (Fig. 2) suggests a response to extracellular releases by the phytoplankton during daylight hours (FUHRMAN *et al.*, 1985). The second increase observed in the early morning is possibly related with the intensified zooplankton activity (excretion, sloppy feeding) during the night (HERNDL & MALACIC, 1987). The O:N ratio is used as a clue to the type of substrate (carbohydrates vs proteins) being oxidized through respiration (GAUDY & BOUCHER 1983). The atomic ratio O:N calculated for zooplankton suggests by its low value (9.4), the ingestion of a food containing a high proportion of nitrogen i.e., microzooplankton or detritus, possibly harbouring attached bacteria and their protozoan predators (OMORI & IKEDA, 1984). According to LANDRY (1981), copepods can switch from herbivory to carnivory depending upon the availability and concentration of plant or animal prey. During the diel cycle analyzed here, the heterotrophic biomass (bacteria + heterotrophic flagellate + ciliates + mesozooplankton) dominated the autotrophic biomass, the ratio of chlorophyll biomass/heterotrophic biomass being 0.33. This situation is not uncommon in oligotrophic waters (FUHRMAN *et al.*, 1989). The night increase of zooplankton biomass (max. at 24 in surface water) was correlated to an increase of the specific activity of digestive enzymes (amylase and trypsin, max. at 3 h, Fig. 3), these observations suggest a coupling between migration and feeding of zooplankton (BOUCHER & SAMAIN 1974). When one specific species of the zooplankton population was considered (*Centropages typicus*) the nutritional activity (max. at 24 h, Fig. 4) corresponded to a parallel increase of the utilisation of autotrophic material (max. at 24 h, Fig. 4) as have already showed (DAGG & GRILL, 1980) for this species.

The results of this study, must be considered as a preliminary approach to the study of complex interactions between planktonic organisms which may vary between seasons. Nevertheless, they illustrate the interest to consider simultaneously the distribution and physiology of planktonic organisms in order to study their possible interactions.

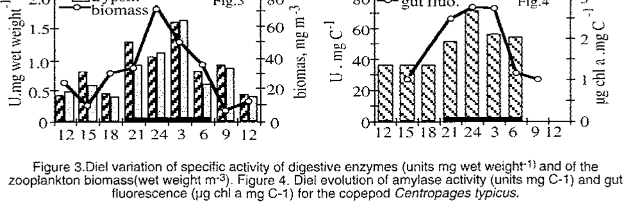

Figure 1. Diel cycle of the abundance of mesozooplankton.Heavy lines on x-axis indicates hours of darkness.Figure 2. Diel evolution of [methyl3H]-thymidine (Tdr) incorporation rates. The right-hand scale indicates the bacterial production (μg C l-1 h-1).

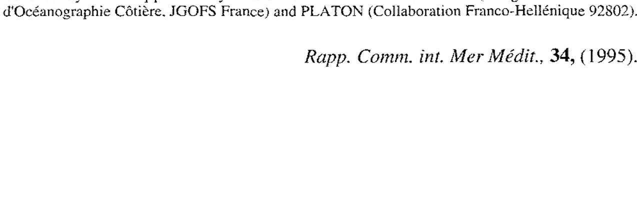

Figure 3.Diel variation of specific activity of digestive enzymes (units mg wet weight^{-1}) and of the zooplankton biomass(wet weight m^{-3}). Figure 4. Diel evolution of amylase activity (units mg C-1) and gut fluorescence (μg chl a mg C-1) for the copepod *Centropages typicus.*

This study was supported by: CEC B/MAST/913008, PNOC (Programme National d'Océanographie Côtière, JGOFS France) and PLATON (Collaboration Franco-Hellénique 92802).

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