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Spring phytoplankton community structure in the Thau Lagoon, France (May 2002)

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Phytoplankton communities were investigated in the French Mediterranean Thau lagoon (75 km², mean depth ca. 4.5 m), where there is important shellfish farming activity. Samples were collected during spring (May 2002), mainly at two sites (MPN and LP) characterised by different eutrophication levels and macrophyte populations, Zostera marina *L. and* Gracilaria bursa-pastoris *(Gmelin) Silva. Taxonomy, cell abundance, carbon content and SHANNON-WEAVER diversity index were determined.*

The most common taxa were nanoflagellates (between 40 and 50% in terms of cells dm^{-3}), diatoms (between 20% and 35%) and Cryptophyceae (around 12%). The sites differed in that Dinophyceae (<5%) were present at the oligotrophic station (MPN) and epiphytic and benthic diatoms at the eutrophicated station (LP). Chlorophyll a *and abundance were higher at LP than at MPN. Carbon content was 8 times higher at MPN than at LP, because of the presence of big dinoflagellates, representing 90% of the biomass, at MPN.*

The authors discuss the species, which are indicators of the eutrophication level, and the important role of taxonomic analysis and compare the results with those of the Venice lagoon.

Key words: Mediterranean lagoon, eutrophication level, phytoplankton, taxonomy, chlorophyll *a*, carbon content

INTRODUCTION

Thau Lagoon covers an area of 75 km², 20% of which is covered by shellfish farming. The average depth is about 4.5 m, but in the middle it reaches 12 m. Freshwater input is poor and the main exchange of sea water is through the Channel of Sète. Hence, the lagoon has a strong marine influence. The salinity spatial variation is poor. On the contrary, seasonal and pluriannual salinity varied between 36 and 40 PSU (TOURNIER *et al.*, 1983). Thau Lagoon has low tidal amplitude (only 2-4% of the total water volume is renewed during any tidal cycle through the two narrow inlets). Wind induces hydrodynamic patterns (MILLET, 1989; DE CASABIANCA & KEPEL, 1999).

Shellfish farming produces an estimated 35000 tonnes per year of oysters and mussels, representing 12% of the French national production (HAMON & TOURNIER, 1981). This means that 500 kg ha^{-1} of nitrogen and 3000 kg ha^{-1} of carbon are deposited (DE CASABIANCA, 1996) and 5 kg ha^{-1} of ammonium are excreted (OUTIN, 1990) every year. These depositions and excretions play a significant role as a source of eutrophication (DE CASABIANCA *et al.*, 1997a) and, therefore, have a strong impact on macrophyte communities (DE CASABIANCA *et al.*, 1997b; DE CASABIANCA & POSADA, 1998 and references therein) and nutrient dynamics (the rate of nutrient fluxes from the sediment to the overlying water is higher in shellfish areas than elsewhere; BAUDINET *et al.*, 1990). Heavily eutrophicated sites are prevalently populated by annual nitrophilous seaweed (such as *Gracilaria* and *Ulva*) whereas oligotrophic zones are dominated by perennial eelgrass (such as *Zostera*).

Numerous papers describe the physical and chemical variations (DE CASABIANCA *et al.*, 1997a and references therein) and macrophyte responses to the environmental conditions in the Thau Lagoon (DE CASABIANCA & POSADA, 1998; LAUGIER *et al.*, 1999; and references therein) but less attention has been paid to the composition of the phytoplankton community. Most papers have referred to models on chlorophyll evolution and a particular group of small eukaryotic Prasinophyceae (COURTIES *et al.*, 1994; CHRÉTIENNOT-DINET *et al.*, 1995; BACHER *et al.*, 1997; CHAPELLE *et al.*, 2000).

In this paper we present the first report on the structure and diversity of the phytoplankton community and the impact of eutrophication on the composition of phytoplankton in the period preceding the summer bloom (DE CASABIANCA *et al.*, 1997a).

MATERIALS AND METHODS

Studied sites

The samplings were carried out in three locations (Fig. 1) characterized by different environmental conditions, especially eutrophication levels (DE CASABIANCA *et al.*, 1997a).

The first station (MPN) was at the northwestern part of the lagoon where the shellfish farming influence begins. The annual mean water depth was 1.5 m. Bottom sediments constituted sand (48%), shell fragments (31%) and silt (21%). The macrophyte community was dominated by *Zostera marina* L. The total inorganic nitrogen was 60±10 μmol l^{-1} and reactive phosphorus was 2±1 μmol l^{-1} (DE CASABIANCA *et al.*, 1996).

The second station (LP) was situated where shellfish farming activity is at its maximum, but not directly beneath the farming installations. It was characterised by the seaweed *Gracilaria bursa-pastoris* (Gmelin) Silva. Mean depth was ca. 1.5 m. The sediment constituted silt (76%) and shell fragments (24%). The total inorganic nitrogen was 64±20 μmol l^{-1} and reactive phosphorus was 4.7±5 μmol l^{-1} (DE CASABIANCA *et al.*, 1996).

The third station (SF) was in the middle of the lagoon where the depth is ca. 8 m., directly beneath the shellfish farming installations about 100 m from LP. The total inorganic nitrogen was 58±15 μgmol l^{-1} and reactive phosphorus was 2.7±2 μgmol l^{-1} (DE CASABIANCA *et al.*, 1996).

Methodology

All measurements were made in good weather conditions (without significant winds or currents) at a depth of ca. 1.2 m on the morning of May 23, 2002. Temperature and salinity were

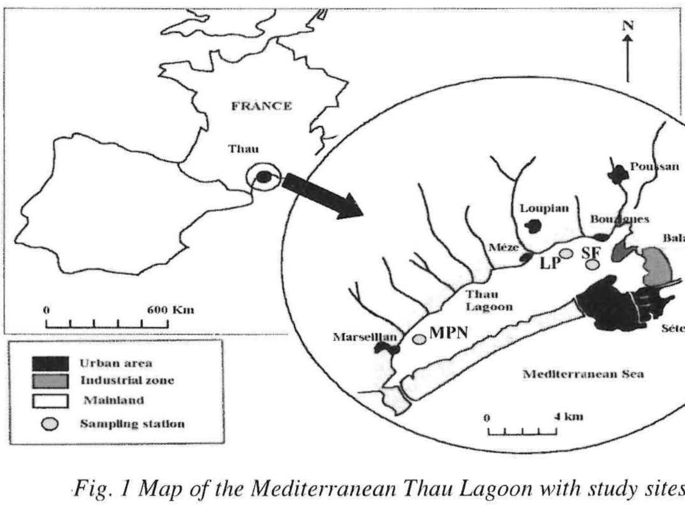

Fig. 1 Map of the Mediterranean Thau Lagoon with study sites marked

measured with a multiparametric probe (WTW Microprocessor, Germany).

Water aliquots, collected in a KEMMER bottle, were filtered *in situ* through GF/F WHATMAN glass fibre filters (0.7 µm pore size) for chlorophyll *a* (Chl *a*) determination. Filters were stored at -20°C. Pigments were extracted by means of 90% acetone and analysed by a fluorimeter (Turner 112).

Aliquots for phytoplankton count were preserved with 4% formaldehyde (neutralised with hexamethylenetetramine). Phytoplankton were counted under a light inverted microscope (AXIOVERT 10, ZEISS) according to the method of UTERMÖHL (1958). Taxonomic identification was carried out using the keys of PERAGALLO & PERAGALLO (1897-1908); HUSTEDT (1927-1966); VANLANDINGHAM (1967-79); ROUND *et al.* (1990); HEIMDAL (1993) and STEIDINGER & TANGEN (1996).

Cell dimensions were measured during the microscope analysis and the biovolume was calculated. Cell carbon content was estimated according to the conversion proposed by EDLER (1979).

The abundance (in term of cells dm^{-3}) of each taxa was considered significant when the value was at least 4% of the total number of cells. The SHANNON-WEAVER index (SHANNON & WEAVER, 1948) was used to estimate community diversity.

RESULTS

Temperature and salinity were 19.5°C and 36.5 PSU, respectively, at all stations. Chlorophyll *a* concentration was five times higher at LP than at MPN (6.68 and 1.24 µg dm^{-3}, respectively; Table 1) and intermediate at SF.

Table 1. List of identified taxa at three sites in Thau Lagoon, France. Abundance is expressed as cells, carbon content as µg dm^{-3} and chlorophyll a as µg dm^{-3}

	MPN Abundance	LP Abundance	SF Abundance	MPN Carbon	LP Carbon	SF Carbon
BACILLARIOPHYCEAE						
Amphora veneta Kützing		17700			2.40	
Chaetoceros cfr. *affinis* Lauder	141604			8.15		
Chaetoceros socialis Lauder		336308			2.32	
Cocconeis molesta Grunow		159304			3.96	
Cocconeis scutellum Ehrenberg		53101			5.61	
Cylindrotheca closterium Reimann et Lewin		17700			0.44	
Fragilaria sp.	53101		70802	0.77		1.02
Navicula cryptocephala Smith	17700			0.43		
Navicula lanceolata Ehrenberg	17700		17700	1.63		1.63
Navicula sp. (<10 µm)	35401	159304	53101	0.26	1.85	0.38
Nitzschia dissipata var. *media* Grunow		17700			0.67	
Nitzschia frustulum Grunow		35401	53101		0.50	0.56
Nitzschia sp.		35401			0.79	
Pleurosigma formosum Smith		17700			0.91	
Thalassiosira sp.	53101		35401	1.75		1.16
CHLOROPHYCEAE						
Chlorophyceae indeterminated	35401	53101		0.70	1.05	
CRYPTOPHYCEAE						
Cryptophyceae indeterminated	159304	194705	141604	0.92	1.12	0.82
DINOPHYCEAE						
Prorocentrum cfr. *lima* Dogde	53101			137		
Prorocentrum cfr. *rostratum* Stein		17700	53101		16.6	37.3
NANOFLAGELLATAE	566414	796520	885022	2.09	2.93	3.26
TOTAL	**1132828**	**1911648**	**1309832**	**153**	**41.2**	**46.1**
CHLOROPHYLL *A*	**1.24**	**6.68**	**1.41**			
SHANNON DIVERSITY INDEX (log_2)	**2.37**	**2.71**	**1.74**			

Phytoplankton was more abundant at LP than at MPN while an intermediate value was recorded at SF. On the whole, 15 diatoms and 3 dinoflagellates were observed. Nanoflagellates (spherical cells <5 µm) were the dominant taxa at all sites (49% at MPN, 42% at LP and 67% at SF). Diatoms represented 21%, 34% and 13% of the total counted cells at MPN, LP and SF, respectively. The presence of dinoflagellates was insignificant at LP whereas it was higher than 4% of the total abundance at MPN and SF.

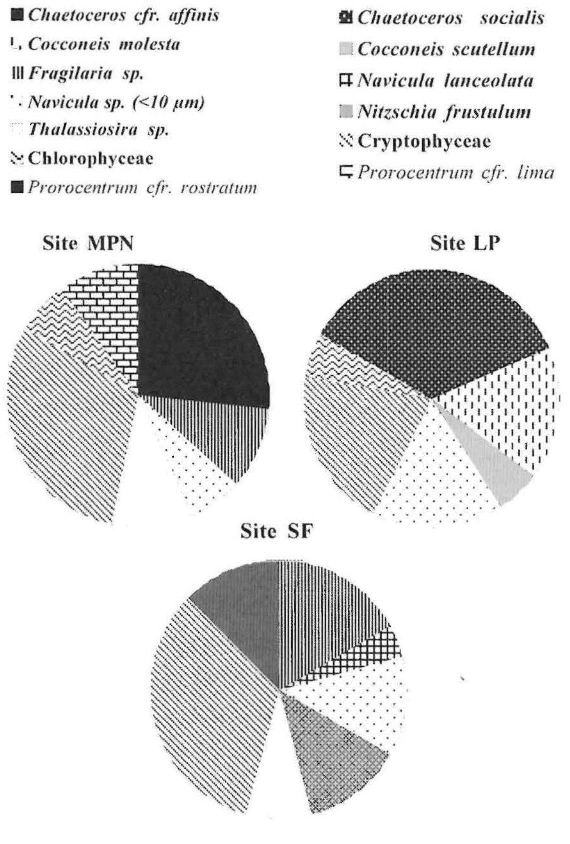

Fig. 2. Taxa in the phytoplanktonic community composing at least 4% of the total abundance (cells. dm^{-3})

The percentages of taxa, not including nanoflagellates, are shown in Fig. 2. Cryptophyceae and the diatom *Navicula* sp. (<10 µm) were significantly abundant in all stations. At MPN, diatoms were, on the whole, represented by 6 species, among which *Chaetoceros* cfr. *affinis* was the most abundant. Among the 10 species identified at LP, *Chaetoceros socialis, Cocconeis molesta, C. scutellum* and *Navicula* sp. (<10µm) were significantly abundant.

The SHANNON-WEAVER indices were 2.37, 2.71 and 1.74 at MPN, LP and SF, respectively (Table 1). The carbon content was ca. eight times higher at MPN than at LP. The high value was due to the large dinoflagellate presence (*Prorocentrum* cfr. *lima*) which accounted for 90% of the total biomass at MPN.

DISCUSSION AND CONCLUSIONS

Phytoplankton generally varies quite rapidly in response to weather conditions. In temperate zones, the annual trend is very low abundance in late autumn and winter, an increase in early spring and the main bloom during summer (DE CASABIANCA *et al.*, 1997a; FACCA *et al.*, 2002). The present study was planned for May when the abundance is higher than in winter but the summer bloom has not yet started. This allowed better comparison between sites as DE CASABIANCA *et al.* (1997a) observed that the summer bloom occurs earlier in some sites that in others (i.e., at LP in June-July 1995 and at MPN in August). These authors reported that values were minimal (0.001-0.79 µg dm^{-3}) in November-December and progressively increased from February to May when the chlorophyll *a* concentration approached 1 µg dm^{-3} at MPN (populated by *Zostera*) and ranged 1.5-2 µg dm^{-3} at LP (dominated by *Gracilaria)*. Chlorophyll *a* rapidly increased in June-August to 14 and 10 µg dm^{-3} at LP and MPN, respectively.

At MPN we found the same results as observed in May 1995 by DE CASABIANCA *et al.* (1997a) but, at LP, the concentrations were about three times higher, suggesting that the bloom occurred earlier at this station.

The increasing eutrophication level was investigated in the Thau lagoon by DE CASABIANCA *et al.* (1997a). These authors suggested that the major source of eutrophication was the nearby shellfish farming activity. Urban and agriculture inputs, in fact, do not explain the high nutrient concentrations recorded in the basin. The present study confirms the previously established eutrophication level in terms of physical and chemical parameters and dominant macrophyte communities. The eutrophication level at LP was high whereas MPN was oligotrophic. The different levels are well highlighted by both chlorophyll *a* concentration and cell abundance. Different spatial variations may be found directly beneath shellfish farming installations where molluscs assimilate phytoplankton (CHAPELLE *et al.*, 2000) in spite of the high biodeposition on silt sediments (DE CASABIANCA, 1996).

The structure of the phytoplankton community differed among the study sites. Diatoms were particularly useful in distinguishing environmental conditions. The distribution of nanoflagellates confirms the dominance observed by COURTIES *et al.* (1994) and CHRÉTIENNOT-DINET *et al.* (1995). Diatoms were more abundant at LP than at MPN (0.85 and 0.32 x 10^6 cells dm^{-3}, respectively) where *Zostera* favours the settlement of particulate matter. On the contrary at LP, in addition to pelagic species (*Chaetoceros*), epiphytic (*Cocconeis*) and benthic (*Pleurosigma*) taxa were suspended in the water column. This explains the high SHANNON-WEAVER value. This site was also characterised by species that are tolerant to organic pollution such as small *Navicula*. Although the highest abundance and chlorophyll *a* concentration were recorded at LP, the carbon content was higher at MPN than in LP, the most eutrophicated area. This was mainly due to the presence of big dinoflagellates in MPN that were absent in LP. Taxonomic analyses, which had not been carried out previously, help us understand local variations of chlorophyll *a* and carbon content. This preliminary study should be developed on spatial and temporal scales to increase our knowledge of the lagoon ecosystem and establish the carbon and chlorophyll *a* balance.

The annual chlorophyll *a* trend in Venice Lagoon (Italy) was quite similar to that observed at Thau (FACCA *et al.*, 2002) although the two lagoons have different morphological and hydrodynamic characteristics. Common features are the temperature variation (RIGOLLET *et al.*, 1998) and the intense use of resources. In Venice Lagoon, two sites are comparable to MPN and LP. The first is Alberoni which is populated by *Zostera* and the second is San Giuliano into which urban sewage flows (FACCA *et al.*, 2002). These sites have different trophic levels which, based on the nutrient concentrations, are higher at San Giuliano than at Alberoni. Dissolved inorganic nitrogen (DIN) in the water column was 3-4 times higher and reactive phosphorus 4-5 times higher at Thau than at Venice Lagoon (DE CASABIANCA *et al.*, 1997a; FACCA *et al.*, 2002). Consequently, chlorophyll *a* concentrations were lower at Venice than at Thau. In May 2002, the chlorophyll *a* concentration at MPN was two times higher than at Alberoni in May 1999 and it was four times higher at LP than at San Giuliano (FACCA *et al.*, 2002) although the temperature in that month was 2-3°C higher at Venice than at Thau.

The SHANNON-WEAVER diversity index was about 1 point higher at the Venice sites than at the Thau sites. At Alberoni, as at MPN, Cryptophyceae were abundant and nanoflagellates constituted 44% of the total abundance; among diatoms, *Thalassiosira* sp. was significantly present. At San Giuliano, a completely different community was observed. Nanoflagellates were not as abundant (only 15%) and Prymnesiophyceae was the most important flagellate taxon. At LP, *Gracilaria* was extremely abundant so many epiphytes were present; at San Giuliano, on the contrary, macroalgae lacked and numerous benthic diatoms were identified.

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Struktura fitoplanktonske zajednice u proljeće u Laguni Thau, Francuska (svibanj 2002)

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SAŽETAK

Proučavane su fitoplanktonske zajednice u francuskoj laguni Thau na Mediteranu (75 km^2, prosječna dubina 4,5 m), koja je važno uzgajalište školjkaša. Uzorci su prikupljani za vrijeme proljeća (svibanj 2002) pretežito na dvije lokacije (MPN i LP) koje obilježavaju različiti stupanj eutrofikacije i različite populacije makrofita (*Zostera marina* L. i *Gracilaria bursa-pastoris* (Gmelin) Silva. Određivani su taksonomija, numerička abundancija, sadržaj ugljika i raznolikost vrsta pomoću SHANNON-WEAWER-ovog indeksa.

Uobičajene su bile nanoflagelatne vrste (između 40 i 50%, u izrazima volumena, dm^{-3}), dijatomeje (između 20% i 35%), te kriptoficeje (oko 12%). Razlika između lokaliteta bila je u tome što su dinoficeje (<5%) bile prisutne na oligotrofnoj postaji (MPN), a epifitske i bentoske dijatomeje na eutrofiziranoj postaji (LP). Klorofil *a* i abundancija su bili viši na MPN nego na LP radi prisustva velikih dinoflagelata koji su predstavljali 90% biomase na MPN.

Autori diskutiraju o vrstama koje su indikatori eutrofikacijske razine, dobivene rezultate uspoređuju s onima za venecijansku lagunu, te naglašavaju važnost taksonomskih analiza.

Ključne riječi: mediteranska laguna, nivo eutrofikacije, fitoplankton, taksonomija, klorofil *a*, sadržaj ugljika