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BIODIVERSITY THROUGH TWO GROUPS OF MICROZOOPLANKTON IN A COASTAL LAGOON (ÉTANG DE THAU, FRANCE)

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MICROZOOPLANKTON
BIODIVERSITY
BIOMASS STRUCTURES
ENVIRONMENTAL IMPACT
MEDITERRANEAN COASTAL LAGOON

SUMMARY. – Between land and sea, coastal lagoons appear to be original entities, as compared to these two adjoining ecosystems. During 1994, a survey has been scheduled for the Etang de Thau, a 70 km² coastal lagoon of the north-western Mediterranean Sea, to explore the zooplankton function in the shellfish culture biocoenosis. In the present study, two groups of microzooplankton were especially emphasized, the tintinnids (Protozoa Ciliata) and the rotifers (Metazoa Rotatoria), which have not been studied on this site yet, and have often been absent from population studies related to marine or lagoon environments. Some patterns of biodiversity had been put forward through these taxocoenoses : *biomass diversity* (abundance difference between lagoon and sea, systematic biomass reduction toward the shellfish culture area inside the lagoon), *structural diversity* (lagoon-sea difference and similitude for the stations inside the lagoon, except when the E-SE winds affected the water masses), and *taxa diversity* (taxa contribution to the Shannon's diversity index which enabled to identify "characteristic" species and "destructuring" species).

MICROZOOPLANKTON
BIODIVERSITÉ
STRUCTURES DES BIOMASSES
IMPACT ENVIRONNEMENTAL
LAGUNE MÉDITERRANÉENNE

RÉSUMÉ. – Entre terre et mer, les lagunes littorales constituent des entités écologiques originales vis-à-vis des écosystèmes adjacents. Au cours de l'année 1994, un suivi a été effectué dans l'Etang de Thau, une lagune nord-méditerranéenne de 70 km² de superficie. Le but était d'évaluer la contribution du zooplancton dans le fonctionnement de la biocénose des tables conchylicoles. Ce suivi a permis de s'intéresser plus particulièrement à deux groupes du microzooplancton encore non étudiés jusqu'ici sur ce site, les Tintinnidés et les Rotifères. A travers ces deux groupes, quelques aspects de la biodiversité ont pu être mis en évidence : une *diversité d'abondance* (biomasses différentes entre la lagune et la mer, appauvrissement systématique des biomasses dans la zone conchylicole), une *diversité de structure de peuplement* (différence mer-lagune et similitude des deux stations de l'étang tant que n'interfère pas l'action des vents E-SE), enfin une *diversité spécifique* (la contribution des taxons à l'indice de diversité de Shannon a permis d'identifier des espèces « caractéristiques » et des espèces « destructurantes »).

INTRODUCTION

Between land and sea, coastal lagoons appear to be original entities, as compared to these two adjoining ecosystems. During 1994, a survey has been scheduled for the Etang de Thau, a 70 km² coastal lagoon of the north-western Mediterranean Sea, with purpose to explore the zooplankton function in the shellfish culture biocoenosis (one fifth of the lagoon surface – Fig. 1, A, B, & C – produces yearly 40 000 tons of shellfish). In the present study, two groups of microzooplankton were especially emphasized, the tintinnids (Proto-

zoa Ciliata) and the rotifers (Metazoa Rotatoria), which were only studied as qualitative information (Mathias & Tcherniakofsky 1932; Mathias & Euzet 1951, 1962), and have often been absent from population studies related to marine or lagoon environments. Through these two groups of microzooplankton, a feature of biodiversity will be examined.

Diversity in terms of the taxa composition and population abundances, as well as of their assemblage structures has been shown for the mesozooplankton in the Etang de Thau (Lam-Hoai & Amarnieu 1989, Jouffre 1989). Besides, Lam Hoai *et al.* (1987) used the Divdrop procedure (Rajczyk &

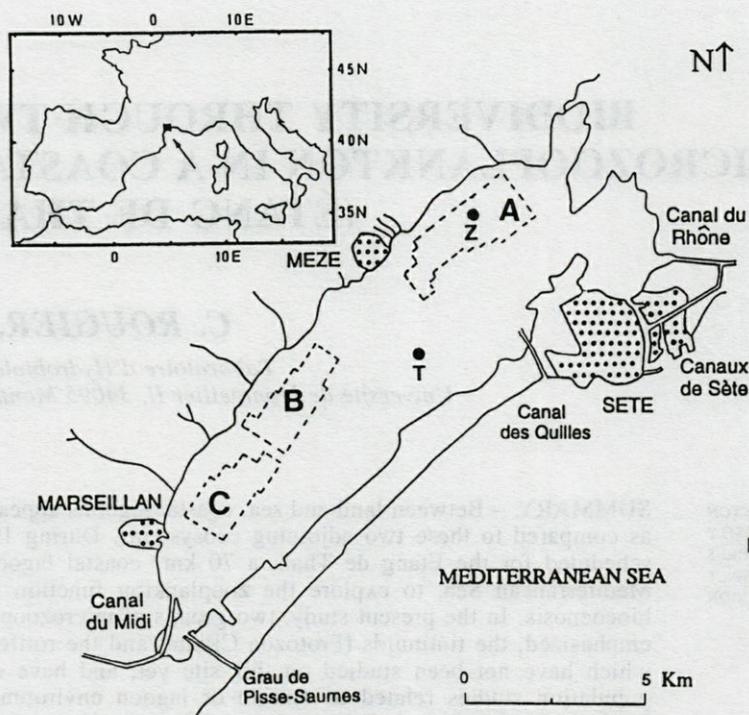


Fig. 1. – Etang de Thau and the shellfish culture sectors A, B and C. The three sampling stations, T, Z and M, are positioned inside and outside the lagoon.

Padisak 1983) to define characteristic species from faunistic lists of the mesozooplankton in the lagoon.

This experience conducted to look for how diversity of the tintinnid and rotifer populations took place in two sites inside the Etang de Thau, with and without anthropogenic impact, and in a marine station next to the lagoon, surveyed in different periods of the year.

MATERIAL AND METHODS

The data were obtained from two stations (T and Z, Fig. 1), and from another station (M) on the seaside. Station T is situated in the central area (7 m deep) while Station Z is positioned in middle of a shellfish culture area (A), near the lagoon NW bank (5 m deep), and not far from the Canaux de Sète (more than 10 m deep) through which most of the water exchanges between the lagoon and the sea occur. More details related to tidal movements and to the environment were given by Lam Hoai & Amanieu (1989)

The survey was carried out daily, during 1994 within four sampling periods: 21 to 25 March (1), 20 to 24 June (2), 26 to 30 September (3), and 28 November to 2 December (4). They corresponded approximately to the major events in the oyster culture (growth, reproduction, post-breeding and pre-wintering periods). As new input compensates any harvest process, it is supposed that no significant impact affects the shellfish

culture system. The 5-day replicating method may reduce the variation in catch of zooplankton. Each daily zooplankton sample was made up of three vertical net tows in the station, from -2 m deep up to the surface, by means of a net of 40 μm mesh size and 0.3 m diameter opening. The plankton material was then fixed in a neutral formal solution (4%), slightly colored with the Rose Bengal to obtain the best contrast for sorting the organisms.

Because of the extremely high density of some samples, these were divided by successive fractions (Folsom splitter), so as to facilitate the sorting and to avoid clusters during the numeration process. The count of zooplankters, the measure of their size and the estimation of their biovolume were realized by an image analysis technique proposed by Lam Hoai (1991) and Lam Hoai & Gril (1991). In this technique, a zooplankton individual viewed under microscope appears in this device as a silhouette which depends on the image contrast. This silhouette may be characterized by its perimeter and its surface, which define a specific form factor. To access the third dimension of the object, a morphometric model which preserves the form factor of the organism, and therefore of its volume, was used. According to Mullin (1969) and Omori & Ikeda (1984), if the specific weight of an animal is close to 1, it is reasonable to consider the equivalence between its volume and its wet weight ($1 \text{ cm}^3 \approx 1 \text{ g}$). The density and wet biomass were expressed per cubic meter.

Records of environmental conditions complete the plankton sampling. Meteorological data were limited to the direction and force of the winds. They have been recorded *in situ* by B. Bibent (pers. com., 1995) with a CIMEL data logger meteorological station. The water

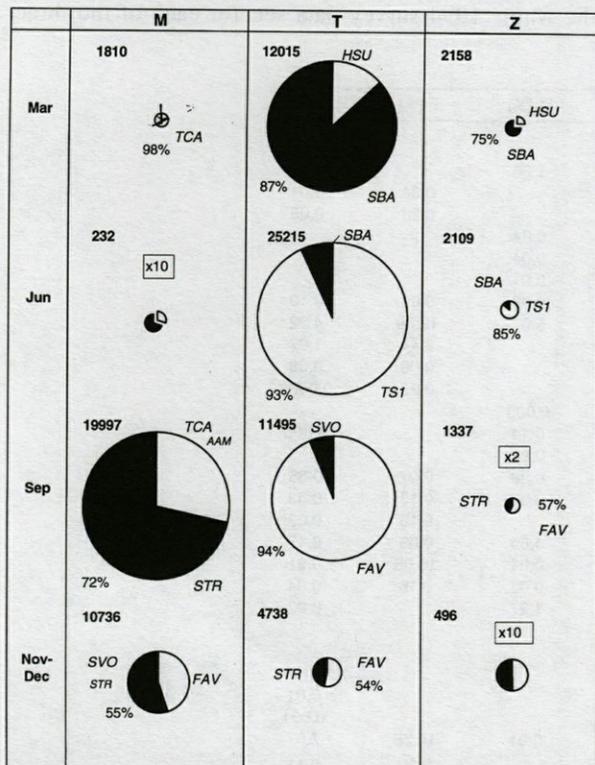


Fig. 2. - Total biomasses of the tintinnids and rotifers figured (top left corner) in proportion to the size of circular diagrams. Some diagrams were magnified by a magnification factor (framed number). The highest biomass percentage of the tintinnids (unfilled sectors) or of the rotifers (filled sectors) is positioned close to the corresponding sectors, so is the dominant population (see Table I for explanation of taxa codes).

temperature (°C) and the salinity (PSU) have been measured with a WTW 196 salinometer and a Tetracon 96T sensor cell.

Identification of tintinnids (ciliates) is made from their lorica, according to classifications of Jörgensen (1924), Kofoid & Campbell (1939), Margalef & Duran (1953) and Balech (1959). Nevertheless, Laval-Peuto & Brownlee (1986) underline the great variability of this shell. For this reason, *Tintinnopsis butschlii* is considered as a phenotype of *Tintinnopsis campanula* (TCA in Table I). Some tintinnids have not been identified to the specific level: *Tintinnopsis sp.2* (TS2) and *Tintinnidium sp.* (TIN). *Favella spp.* taxa (FAV) mainly includes *Favella serrata* (Möb.) Jörgensen and sporadic individuals of *F. ehrenbergii* (Clap. & Lachm.) Jörgensen. Classification criteria of Voigt (in Koste 1978) as well as those of Rousselet (1909) Remane (1929), Hollowday (1949), Berzins (1960), Arndt *et al.* (1990), were used to identify the rotifers. The great majority of species encountered during 1994 belongs to an alicaric group, the Family of Synchaetidae.

The net microzooplankton composition (percentage) in each station (Table I) was computed from the wet biomass daily data. The tintinnid and rotifer 5-day averaged global biomasses were used to look for the abundance diversity in space and time (Fig. 2). The

5-day averaged biomasses from different populations of these two taxocoenoses form a basis for an exploration of their specific and structural diversities. If the Shannon (1948)'s diversity index is assumed to represent an abundance structure, the taxa contribution to this index may be estimated with the following Divdrop procedure, proposed by Rajczy & Padiśak (1983):

From a number of observations (spatial or temporal samples) on a biocoenosis or an assemblage, each sample *j* possesses a taxa abundance distribution (density or biomass) which may be represented by the Shannon's diversity index H_j (bits). This index was calculated from the zooplankton wet biomasses in this study. If one *k* taxa is removed from this sample, the new diversity index H_{jk} calculated with the remaining taxa differs from H_j by the quantity:

$$dH_{jk} = |H_j - H_{jk}|.$$

This difference in absolute value expresses the contribution of the *k* population to the diversity H_j . When its relative value dH_{jk} / H_j is superior to a threshold fixed to 0.05, one should admit that the *k* taxa may consistently contribute to the diversity of the sample *j*. It seems not to be reasonable to give any meaning to contribution values of the samples with no more than 3 taxa. It is equally evident that the procedure does not eliminate the arbitrary aspect concerning the minimum threshold contribution. However, the taxa contribution can be positive (+) or negative (-). In a given situation, the negative contribution of a taxa means that its removal from the assemblage has the consequence of an increase of the diversity index. Such a result may be due to a particular event which had affected this population.

RESULTS

During the 1994 survey, difference of temperature was estimated to 5.7 °C at the seaside M station, 9.2 °C in the central part of the lagoon (Station T) and 8.5 °C in the lagoon shellfish culture area (Station Z). The corresponding salinity differences over these sites were respectively 4.5 (PSU) at the seaside, 6 and 6.5 inside the lagoon.

Global abundance diversity of the tintinnid and rotifer taxocoenosis

In the coastal M station, tintinnids and rotifers wet biomasses were very low in the March and June periods (maximum 1810 $\mu\text{g}\cdot\text{m}^{-3}$). They increased ten times by September (19997 $\mu\text{g}\cdot\text{m}^{-3}$), especially because of blooms of the rotifer *Synchaeta triophthalma* (STR) and of the tintinnid *Tintinnopsis campanula* (TCA). This level remained high (10736 $\mu\text{g}\cdot\text{m}^{-3}$) by November-December (Fig. 2).

Table I. – Identified taxa with their percentages estimated from the whole 1994 survey data set, for each of the three sampling stations.

Taxa	Codes	M (%)	T (%)	Z (%)
Tintinnids				
<i>Amphorides amphora</i> (Cl. & L.)	AAM	1.60		0.01
<i>Codonella acerca</i> Jörg.	CAC		0.04	0.01
<i>Codonella cratera</i> (Leidy)	CCR		0.23	0.05
<i>Codonella galea</i> Hck.	CGA	0.04		
<i>Codonellopsis morchella</i> (Cl.)	CMO	0.04		
<i>Codonellopsis orthoceros</i> (Hck.)	COR	0.01		
<i>Eutintinnus fraknoi</i> Dad.	EFR	0.08	0.02	0.10
<i>Favella</i> spp.	FAV	5.07	12.39	4.22
<i>Helicostomella subulata</i> (Ehr.)	HSU		2.44	1.97
<i>Metacytis mediterranea</i> (Mereschk.)	MME		0.09	0.08
<i>Parundella aculeata</i> Jörg.	PAC		0.27	0.0003
<i>Petalotricha ampulla</i> (Fol) Kent	PAM	0.003		
<i>Rhabdonella spiralis</i> (Fol)	RSP	0.14		0.005
<i>Salpingella acuminata</i> (Cl. & L.)	SAC	0.01		
<i>Stenosemella ventricosa</i> (Cl. & L.)	SVE	0.28	0.07	0.35
<i>Tintinnidium</i> sp.	TIN	0.33	0.13	0.33
<i>Tintinnopsis beroidea</i> (Stein)	TBE		0.15	0.03
<i>Tintinnopsis campanula</i> (Ehr.)	TCA	4.69	0.03	0.17
<i>Tintinnopsis corniger</i> Hada	TCO	0.01	16.08	6.91
<i>Tintinnopsis cylindrica</i> Daday	TCY	0.03	0.16	0.04
<i>Tintinnopsis</i> sp2	TS2	1.27		0.02
Rotifers				
<i>Brachionus plicatilis</i> (Muller)	BRA			0.01
<i>Colurella colurus</i> (Ehr.)	CCO			0.001
<i>Synchaeta baltica</i> Ehr.	SBA	0.01	10.26	7.67
<i>Synchaeta cecilia</i> Rousselet	SCE		0.22	0.11
<i>Synchaeta grimpei</i> Remane	SGR	0.02		
<i>Synchaeta neapolitana</i> Rousselet	SNE	1.35	0.22	0.14
<i>Synchaeta triophthalma</i> Lauterborn.	STR	15.46	1.10	3.04
<i>Synchaeta vorax</i> Rousselet	SVO	4.42	0.80	0.61
<i>Testudinella</i> sp.	TES	0.001		
<i>Trichocerca marina</i> (Daday)	TMA	0.07	0.11	0.11

The evolution is different inside the lagoon where biomasses of these two groups of microzooplankton were already consistent in March. This period was marked by a very high abundance of *Synchaeta baltica* (SBA, 10376 $\mu\text{g}\cdot\text{m}^{-3}$ at Station T). Tintinnid and rotifer biomasses reached the top level by June with more than 25000 $\mu\text{g}\cdot\text{m}^{-3}$ at Station T (important bloom of *Tintinnopsis corniger*, TCO). But whatever is the season, the shellfish culture Station Z showed a very marked biomass depletion as compared to the observed abundance at Station T, where biomasses were approximately ten times higher.

Tintinnid and rotifer taxa diversity

During the four periods of the 1994 survey, the tintinnid specific richness (taxa number) in the lagoon central Station T was slightly lower than that at the seaside M station (13 versus 15). A contrario, the marine station included only four out of six rotifer species of the genus *Synchaeta* found at Station T. The shellfish culture Z station was completed with populations issued from coastal waters driven into the lagoon by E-SE winds such as the tintinnid *T. campanula* and especially the rotifer *S. triophthalma* in the September period.

Eight tintinnid taxa (AAM, CGA, CMO, COR, PAM, RSP, SAC, and TS2) and one sporadic rotifer species (SGR) were identified in the seaside station; six tintinnids (CGA, CCR, HSU, MME, PAC and TBE) and two rotifers (SCE, SBA) encountered only in the lagoon central station (Table I).

Structural diversity of the tintinnid and rotifer assemblages

It was assumed that an assemblage composition forms an abundance structure of this assemblage. Thus the structures of tintinnid and rotifer assemblages at the stations inside the lagoon (T & Z) did not differ significantly during the March and June periods: *S. baltica* (SBA), *H. subulata* (HSU) and *T. corniger* (TCO) were dominant populations in these stations (Fig. 2). Meanwhile a quite different structure was observed at the seaside M station: the major tintinnid component was *T. campanula* (TCA) population and the rotifers were represented by the occurrence of *Synchaeta vorax* (SVO) and the sporadic occurrence of *S. grimpei* (SGR), which was not found inside the lagoon. Assemblage structures at the T and Z stations were still similar, if hydrodynamic pattern

Table II. - Tintinnids' and rotifers' contribution to the Shannon's diversity index, HT and HR respectively during the 1994 survey. Sampling periods figured as rank numbers added to the station symbols M, T and Z. Characteristic populations are supposed to contribute to more than 5% of the index value (+ and - plots), and minus plots (-) design "destructuring" species in the assemblage. T (tintinnids) and R (rotifers) list the number of characteristic populations over the assemblage global specific richness. The O symbols indicate taxa belonging to the assemblages with no more than 3 species groups (see Table I for explanation of taxa codes).

a.		TINTINNIDS											
Taxa	M1	M2	M3	M4	T1	T2	T3	T4	Z1	Z2	Z3	Z4	
AAM			+										
CAC													
CCR							+				+		
CGA													
CMO				+									
COR													
EFR			+		+		+		+				
FAV		+	+	-		+	-	-		+	-	-	
HSU					-	+	+		-	+			
MME							+				+		
PAC								+					
PAM													
RSP				+									
SAC													
SVE	+		+	+			+	+			+	+	
TBE								+				+	
TCA	+	+	+	+	+				+		+		
TCO		+					+			-	+		
TCY						+			+			+	
TIN	+				+	+			+				
TS2			+	+									
HT	1.03	1.53	2.17	1.40	0.37	0.94	0.83	1.10	0.89	0.57	1.37	0.43	
T	3/7	3/6	6/9	6/11	4/7	5/8	7/8	4/6	5/5	3/7	6/12	4/5	

b.		ROTIFERS											
Taxa	M1	M2	M3	M4	T1	T2	T3	T4	Z1	Z2	Z3	Z4	
BRA													
CCO													
SBA	+				0	+	+	+	+	+	+	+	
SCE								+				+	
SGR	+		+										
SNE			+				+				+		
STR	+	0	-	0	0	+	+	+	+	+	-	+	
SVO		0	+	0		+	+	+		+	+	+	
TES													
TMA	+			0		+	+	+		+	+	+	
HR	1.96		0.78			1.51	0.78	1.80	0.41	1.44	1.11	1.88	
R	4/4		4/7			4/4	5/5	5/6	2/4	4/4	5/6	5/7	

was not disturbed by strong E-SE winds, which were frequent during the fall. As the Shannon's diversity index measures the assemblage structure in term of biomass, "characteristic" populations, identified by their contribution value to this index (Table II, symbols + and -), appeared to vary from one site to another, and from one period to another.

DISCUSSION

Tintinnids and rotifers constituted only a small fraction of the net collected zooplankton in the Etang de Thau: 20.4% of the total zooplankton biomass, and 44.8% of the microzooplankton bio-

mass, according to the season and to the station. Nevertheless their function in the pelagic compartment is obvious. With a high capacity to rapidly colonize a habitat and to use a large spectrum of food resources such as organic matter, bacteria, pico- and nano-plankton (Fenchel 1980, Rassoulzadegan & Etienne 1981, Andersen & Sorensen 1986, Verity 1986, Bernard & Rassoulzadegan 1990, 1993), they may serve as a trophic link between the primary producers and the larger secondary producers (Hernroth, 1983). The matter recycling rate per unit weight of these taxocoenoses is higher than that of the copepods (Rassoulzadegan 1982): a high efficiency metabolism and thus a considerable ecological role in the lagoon ecosystem might be expected.

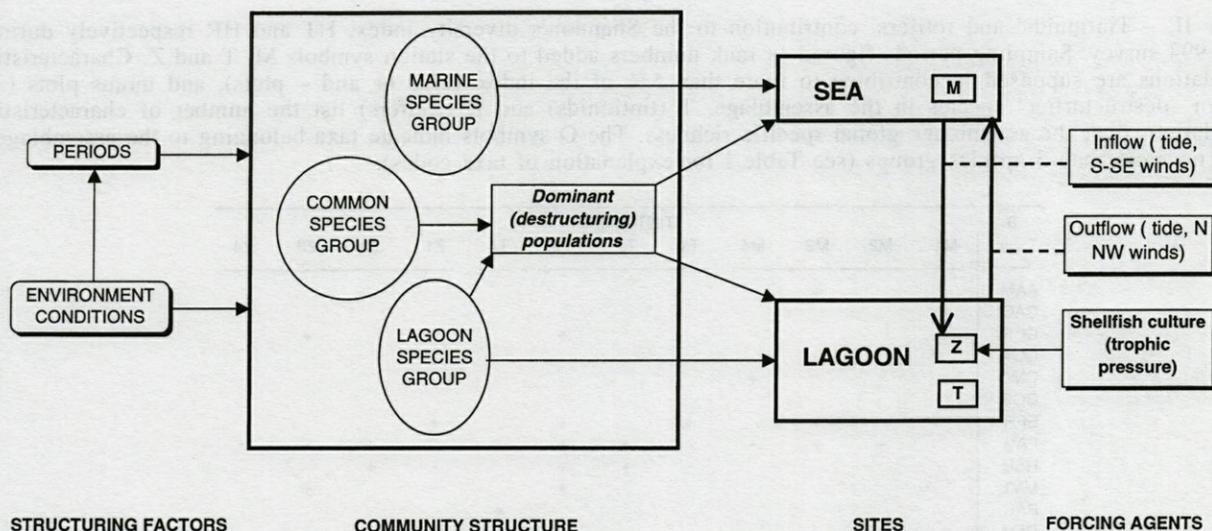


Fig. 3. – Synthetic chart summarizing biodiversity patterns through the tintinnid and rotifer components of the microzooplankton studied during the 1994 survey in the Etang de Thau.

Very low biomasses at Station Z were probably due to the trophic pressure from the oysters and the epibiotic fauna. Such a pressure acted directly upon this microzooplankton in appropriate size fractions (even if the preys were rejected by the filtering mechanism of greater-size predators, their chance of surviving remained reduced). Trophic pressure also indirectly operated upon the phytoplankton biomass, thus reducing the food resources for tintinnids and rotifers.

During the September period, the bloom of *S. triophthalma* population in the seaside station (85% of rotifer biomass) was conspicuous in relation to the almost total absence of this taxa in the lagoon central area (1% of rotifer biomass). This event could not be explained by food shortage for *S. triophthalma* at Station T, for cellular chlorophyll concentration were similar in the sea and in the lagoon, nor by predation, as potential predators, *Acartia sp.*, *Podon sp.*, were present in the three stations. A possible causal factor was the competition with *F. serrata* (FAV), a tintinnid of greater size which had at Station T a biomass 15 fold higher than those observed at the two other stations. However, the fact that *S. triophthalma* high abundance occurred within the September survey (80% of rotifer biomass), during the last two days of strong E-SE winds, pleads for a marine influence at Station Z. Hydrodynamic models proposed by Millet (1989) showed that during the E-SE wind periods, the north-east near shore area (including the Z Station), facing the Canaux de Sète, could be more influenced by the moving water masses than the central area (represented by Station T).

Modifications of the biocoenosis organization can be detected by means of the taxa contributions

to the assemblage in an assumed steady state. The diversity index measures how the taxa abundances are distributed in an assemblage, hence measures its abundance structure. If such a structure is assumed to be a resulting state from ecological conditions within space and time, then the contribution of a given taxa to the assemblage can be estimated through the diversity index. The formerly designed as “characteristic” taxa had systematically contributed to more than 5% to the assemblage diversity index. Among these taxa, a very high abundance level of a single population (e.g. ecological events, blooms,...) is responsible for the structure disturbance. It is the case of the tintinnids *Favella serrata* (FAV, inside the lagoon in September and in all the stations in November), of *Tintinnopsis corniger* (in June in the lagoon), and of *Helicostomella subulata* (HSU, in the lagoon in March). The same bloom effects were attributed to the rotifer *Synchaeta triophthalma* at the seaside and in the lagoon shellfish culture area in September, and *S. baltica* inside the lagoon in March. Among these “destructuring” populations (negative contribution to the Shannon’s diversity index), one tintinnid (*H. subulata*) and one rotifer species (*S. baltica*) characterized the lagoon environment, the others were common to both of the marine and lagoon sites. The diversity contribution approach offers, in a more objective manner, a possibility to identify characteristic taxa from a faunistic list which can be modified over time and space, for example, by ecological events.

Some species appeared to prefer the lagoon environment. When studying the mesozooplankton in the Etang de Thau, Lam Hoai & Amanieu (1989) referred to them as members of the “plankton lagunaire”. In fact, some tintinnid and rotifer populations were found during the 1994 survey,

exclusively in the samples from inside the lagoon. It can be noted that the unexpected occurrence of *S. baltica* (SBA) at the seaside (the first day of the March survey) could be explained by outflows from the lagoon during NW wind. The lagoon populations do not consist of eurythermic and/or euryhaline species well adapted to severe environmental conditions during the year, but they would rather be a succession of opportunistic taxa, taking advantage of available optimal conditions for their development.

CONCLUSION

Amanieu & Lasserre (1982) had underlined: besides dependence and interactions related to their location between land and sea, lagoons are subjected to internal and irregular variations, through which the biocoenosis may be submitted to abrupt and undamped evolution. Fluctuations of the overall biomasses of the tintinnids and rotifers, and variability of their taxa composition, as well as of their assemblage structures may express the populations' response to singular environmental conditions in the lagoon. Tintinnid and rotifer biomasses thus constitute a diversity of structures which would characterize a site and a period. A synthetic chart (Fig. 3) summarizes such diversity patterns through these two microzooplankton components and their functional implication in the lagoon ecosystem. The equilibrium state of these taxocoenoses appears to be precarious; contributions of forcing agents (physical and biological constraints) and of structuring factors (seasonal processes and environmental conditions) are acting to preserve the biodiversity.

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