

# Foraminiferal patterns in two trophically different regions: the northern Adriatic Sea and the southern Levantine Basin

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## **Abstract**

In spite of the fact that the northern Adriatic Sea and southern Levantine Basin are trophically quite different, the benthic foraminiferal standing stocks through the seasons were found to be in the same range. This suggests that the amount of food (organic matter) available at the sediment-water interface was not the major factor that determined the foraminiferal abundances. Our data suggest that not simply the amount of food, but the delicate balance between organic matter supply and oxygenation was the important ecological factor.

The assemblages of the two areas have a lot of taxa in common but they differ significantly with respect to diversity. The Levantine assemblages contain a high amount of species occurring in low frequencies. In the more eutrophic Adriatic Sea the simple diversity is considerably lower, as can be expected in such a seasonally highly variable setting. These assemblages contain more opportunistic taxa than those of the oligotrophic Levantine basin. In the latter, an increase of infaunal taxa with water depth can be observed.

A comparison of the in-sediment distributions of five representative taxa demonstrate a large resemblance for the different stations. Considering the substantial differences in oxygenation as well as organic matter concentration, this implies that the general microhabitat partitioning is inherent to these taxa themselves and not dependent on environmental variation. For most of these taxa, no correlation was found between the average living depth, or the in-sediment distribution, versus oxygenation. An exception formed the miliolids, their in-sediment distribution appeared to be rather strongly dependent on sediment oxygenation.

## 1. Introduction

Our LEV-ADRIA project started in 1996 with the intention to monitor foraminiferal assemblages occurring in two ecologically completely different regions within the Mediterranean Sea, the eutrophic northern Adriatic Sea and the oligotrophic southern Levantine Basin. The rather extreme eutrophication of the northern Adriatic Sea occasionally results in high total standing stocks of foraminifera, certainly as long as oxygen is present (Jorissen et al., 1992). The marine system is strongly controlled by spring run-off from the Po river and by yearly autumn mixing, both playing a major role in the eutrophication. The occasionally high organic loads arriving at the sea bottom in front of the Po-delta cause severe side-effects for the benthic community in the form of anoxia (e.g. Van der Zwaan and Jorissen, 1991; Justic, 1991; Jorissen et al. 1992).

Because of its oligotrophic waters (Azov, 1986, Berman et al., 1984, 1986, Chapter 2), the Levantine basin was expected to represent a more stable environment. The sediments receive relatively low organic loads and offer a more stable environment for the benthic fauna. However, considering the data described in the preceding chapters of this thesis we can conclude that even in this region strong seasonal fluctuations in the foraminiferal assemblage occur, probably driven by increased organic enrichment after seasonal mixing of water layers.

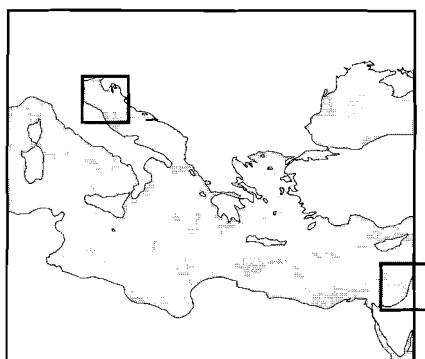
To define more precisely what the differences are between the two systems, and which effects they have on the foraminiferal assemblages, we compared diversity patterns and general assemblage compositions in the two areas. In addition, the abundance patterns, average living depth (ALD) and overall in-sediment distribution for the miliolid group and four taxa that occur relatively abundant at all stations (*Epistominella vitrea*, *Eggerella* spp., *Caronia silvestrii*, and *Bulimina marginata*) are discussed. In order to gain more insight in the impact of oxygen availability, time series of ALD patterns over two years were plotted against sediment oxygenation.

## 2. Material and methods

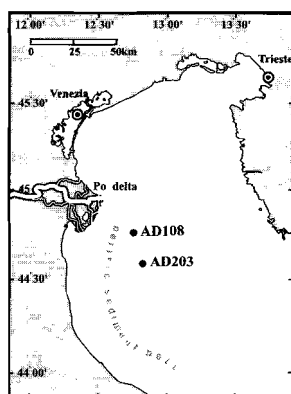
Foraminiferal data was obtained through monitoring cruises in the southern Levantine Basin and northern Adriatic Sea (Fig. 1, Table I). The two Levantine stations S1 and S3 were sampled bimonthly through box coring over the period June '96 to May '98. The two Adriatic Sea stations AD108 and AD203 were sampled eight times between November '96 and June '98. At these stations sampling was done by SCUBA diving. In the Adriatic as well as in the Levantine sediments oxygen-profiles were obtained immediately upon arrival onboard, using micro-electrodes.

Station	Water depth (m)	Latitude	Longitude
LEV51	41	32°22.5'N	34°48.4'E
LEV53	121	32°26.6'N	34°42.8'E
AD108	32	44°45.4'N	12°45.0'E
AD203	36	44°34.0'N	12°48.0'E

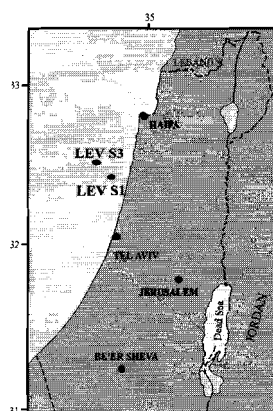
**Table 8-1:** Localities (longitude, latitude, water depth) of the sample stations in the Adriatic Sea and the Levantine Basin



**Figure 8-1:** Sample localities in the Levantine Basin (S1 and S3) and the Adriatic Sea (AD108 and AD203).



northern  
Adriatic Sea



southern  
Levantine Basin

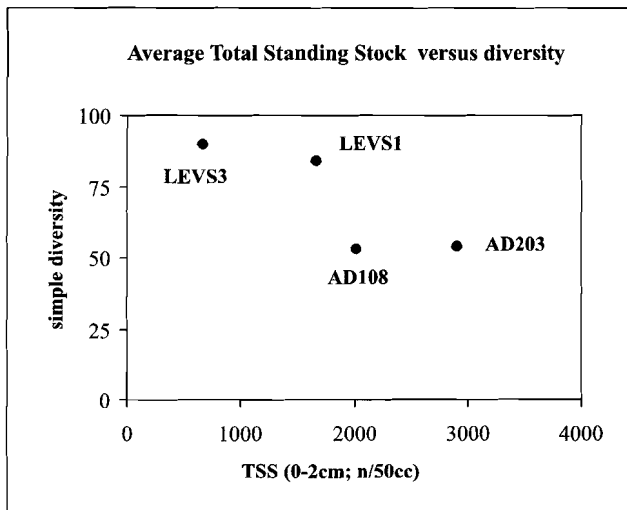
The sediment cores were sliced in slices of 0.5cm (0-2cm) and 1cm (2-10cm); the samples were stored in a mixture of Rose Bengal and ethanol (1g/L). In the laboratory the samples were washed and sieved. Foraminiferal data used for this study is obtained from the 63-595µm size fraction of the four top half cm slices (0-2cm).

### 3. Results

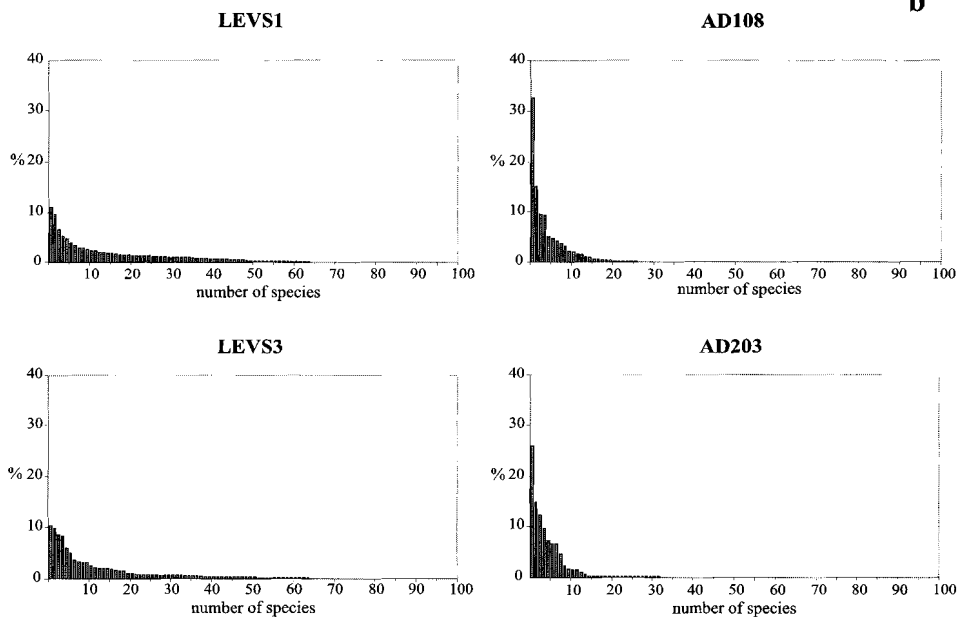
#### 3.1 Diversity and total standing stock patterns

A comparison of simple diversities demonstrates that the assemblages from the stable Levantine area are far more differentiated than those from the ecologically more stressed Adriatic Sea (Fig. 2a). Yet, the bulk of the fauna is not very different: species abundant in the Adriatic Sea are often also common in the Levantine assemblages. More than 70% of the taxa occurring in the Adriatic Sea, also occurs in

**a**



**b**



**Figure 8-2:** a) Average total standing stock (two-years) versus simple diversity found at the four stations; b) histograms of the relative abundances of species averaged over time for the four stations.

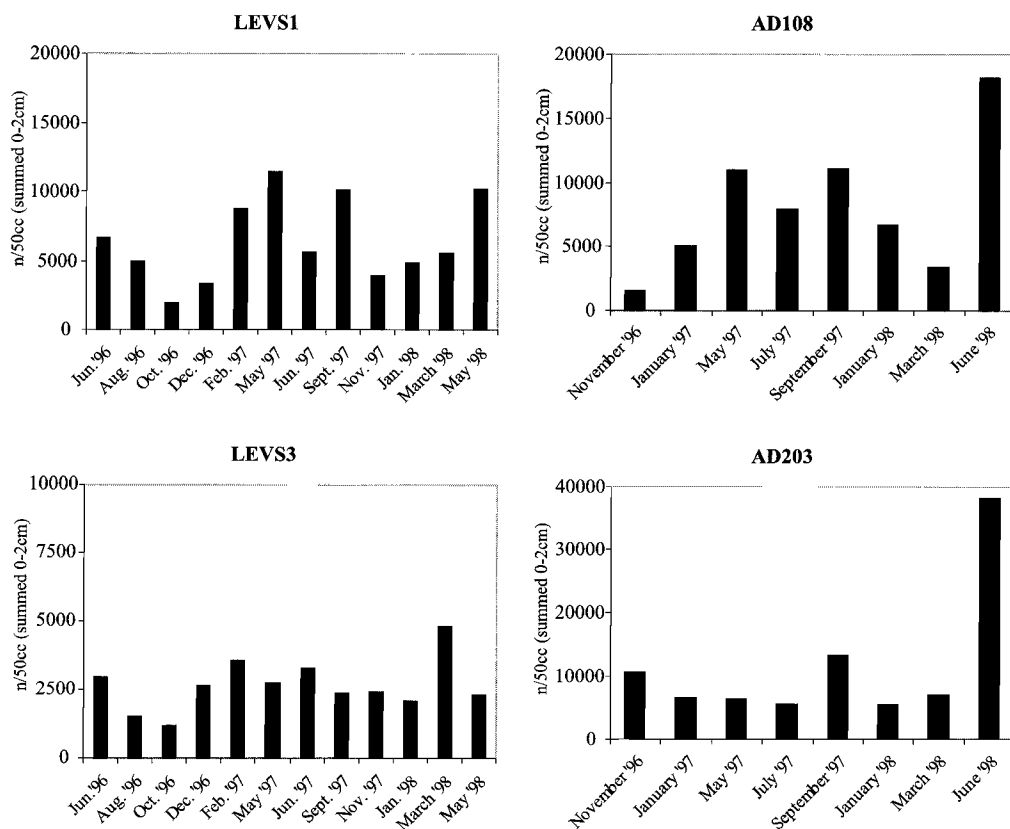
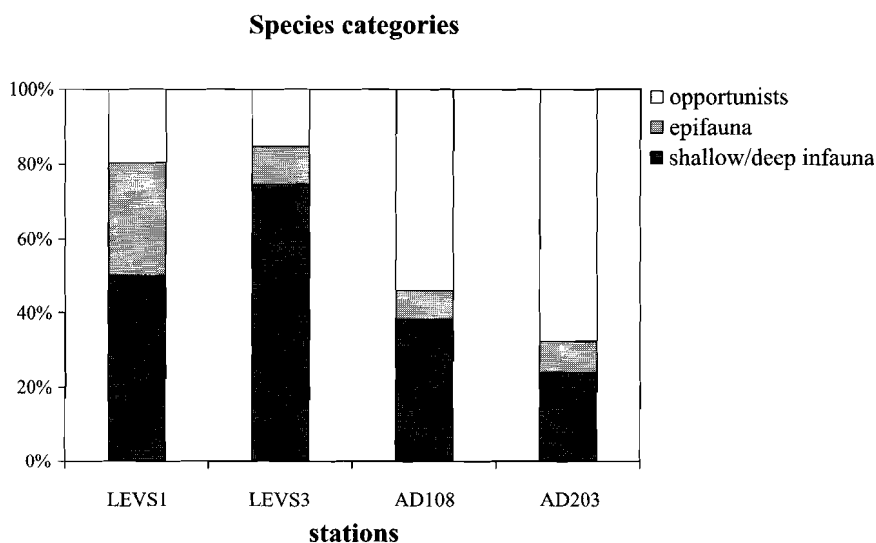


Figure 8-3: Total standing stocks (top 2cm; n/50cc) at the four stations over time.

the Levantine basin (data not shown). The higher diversity in the latter is mainly related to a large number of taxa which are present in low to extremely low relative frequencies (Fig. 2b). The average total standing stocks are inversely related to the diversities and are higher in the Adriatic Sea (Fig. 2a). This can be expected looking at the higher seasonal input of organic matter in the Adriatic Sea compared to the Levantine.

In figure 3 the total standing stocks (TSS) are shown as time series. In stations S1 and AD108 the numbers of foraminifera fluctuated strongly over the two years. At S1 there was a clear seasonal pattern, with increasing numbers after winter/spring and decreasing numbers during autumn and the beginning of winter. At station AD108 the TSS pattern displayed an almost identical pattern, except for the exceptional peak value in June '98. At station AD203 the pattern appeared more stable, with somewhat elevated numbers in November '96 and September '97, and a peak standing stock in June '98. The TSS pattern at S3 was the most constant of the four stations discussed here; the overall abundances were approximately twice as low as the TSS found at S1. The total abundances at S1 were very similar to the TSS found at AD108, but generally 1-2 times lower than those found at AD203.



**Figure 8-4:** Relative abundances of the foraminifera at the four stations categorized within the groups: opportunists, epifauna, or shallow/deep infauna (see text for explanation).

### 3.2 Ecological categories

In figure 4 we summarise the general assemblage composition to get some insight in the main differences. Based on earlier studies we distinguished three categories, i.e. epifaunal, infaunal and opportunistic taxa (see Appendix 1). Although we realise that the assignment of taxa to either of these groups is often arbitrary, we think they give relevant information on the ecological structure of the benthic community.

The proportion of epifaunal taxa decreases with diversity, being highest in both Levantine stations. In station S3 the proportion of (mostly shallow) infauna increases, possible because of the deeper sediment oxygenation at this station (Chapter 6). The largest difference is constituted by the higher proportion of opportunistic species occurring in the Adriatic Sea, being 2–3 times the amount occurring in the Levantine assemblages.

### 3.3 Abundance patterns of the miliolids and four common taxa

In figure 5 the standing stock patterns of the miliolid group and four common taxa (*Epistominella vitrea*, *Eggerella* spp., *Caronia silvestrii*, and *Bulimina marginata*) are shown for all four stations.

At the Levantine station S1 the standing stock of miliolids displayed large fluctuations, and a clear seasonality was visible: low numbers in autumn and winter, highest standing stocks at the end of winter and in spring, and reduced standing stocks again in summer. At station S3 the group of

miliolids was far less abundant and the seasonal pattern less clear. In the Adriatic Sea, the miliolids were more abundant at station AD203 than closer to the Po delta, at AD108. The standing stock at AD203 displayed high numbers in November '96 and June '98, and slightly increased numbers in spring (May '97). At AD108 their numbers increased in spring (May '97) and the following autumn, and peaked in June '98.

Just as for the miliolids, the standing stock pattern of *E. vitrea* at station S1 was almost identical in both years. At station S3 the numbers of *E. vitrea* initially were very low after which they increased (end of winter) and stayed more or less stable for the remainder of the monitoring period. The standing patterns in the Adriatic were similar for both stations although *E. vitrea* was far more abundant at station AD203. At both stations *E. vitrea* occurred with peak values in June '98.

Although the patterns of the miliolids and *E. vitrea* were rather similar for both areas, the absolute numbers differed. Miliolids were more abundant in the Levantine basin whereas *E. vitrea* was more abundant in the Adriatic Sea. The seasonal variability of both taxa was most clear in the shallow station S1 and the Adriatic station 108. The seasonal change was considerably reduced in station AD203 and even more so in the deeper water station S3.

*Eggerella* spp., *Caronia silvestrii* and *Bulimina marginata* basically display a similar pattern as both taxa described before. The seasonal variation reduced going from station 108 in the Adriatic Sea to station S3 in the Levantine. The regularity of the displayed seasonal cycle was often rather disappointing. In this sense absolute standing stocks seem to be decided by a rather complex chain of events instead of being a straightforward response to ventilation or eutrophication.

### 3.4 Average Living Depths (ALD) versus sediment oxygenation

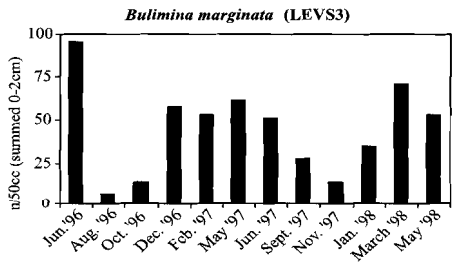
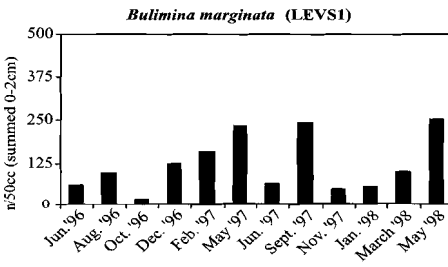
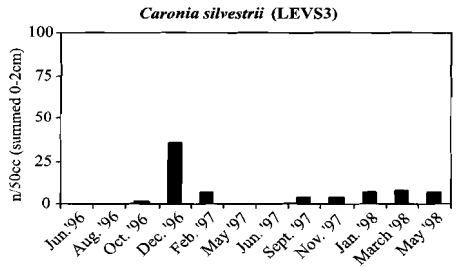
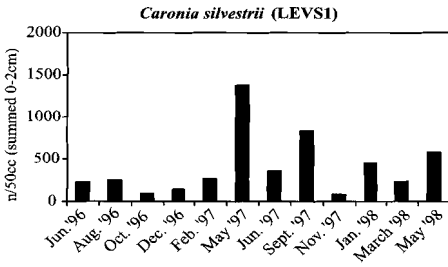
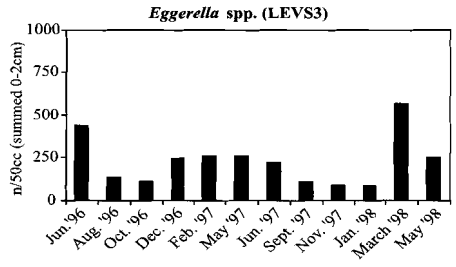
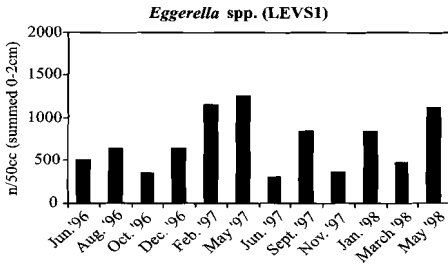
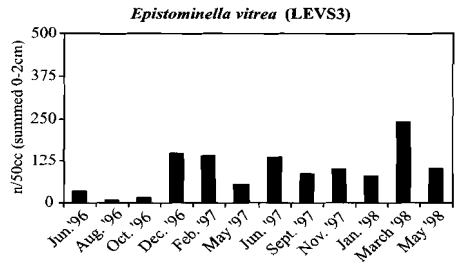
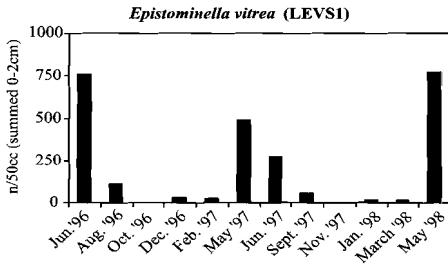
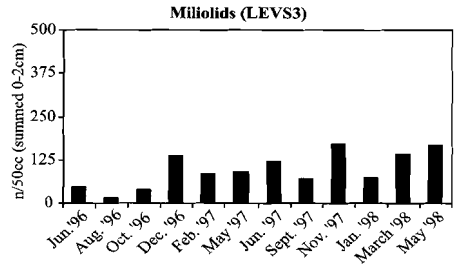
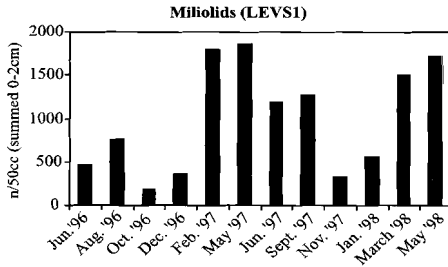
In figure 6 the ALD<sub>2</sub> (average living depth over 0–2cm) of the miliolids and the four other taxa are plotted against the sediment oxygenation. Also the correlation between the relative in-sediment distribution of the species and sediment oxygenation, was calculated (Table II).

The ALD<sub>2</sub> of the miliolids versus oxygenation is shown in figure 6a. The average ALD<sub>2</sub> was rather shallow, but no correlation was found between the ALD<sub>2</sub> and the level of oxygenation. In general, the ALD<sub>2</sub> seemed shallower than the level of 0.1 ml/L oxygen; only at the stations S1 and AD108 it was found to be occasionally below this level. Although there is no clear correlation between the ALD<sub>2</sub> and oxygenation, at all four stations a significant positive correlation was found between the miliolid in-sediment abundance and sediment oxygenation.

*Epistominella vitrea* displayed a variable in-sediment distribution, but generally its ALD<sub>2</sub> was rather

	LEVS1	LEVS3	AD108	AD203
miliolids	+	++	+	+++
<i>Epistominella vitrea</i>	n.s.	n.s.	n.s.	+
<i>Eggerella</i> spp.	n.s.	n.s.	-	n.s.
<i>Caronia silvestrii</i>	n.s.	n.s.	n.s.	n.s.
<i>Bulimina marginata</i>	n.s.	n.s.	+	n.s.

**Table 8-II:** Correlation between the relative in-sediment distribution and sediment oxygenation. (p<0.05 = +/- (positive/negative); p<0.01 = ++; p<0.001 = +++; n.s. = no significant correlation)





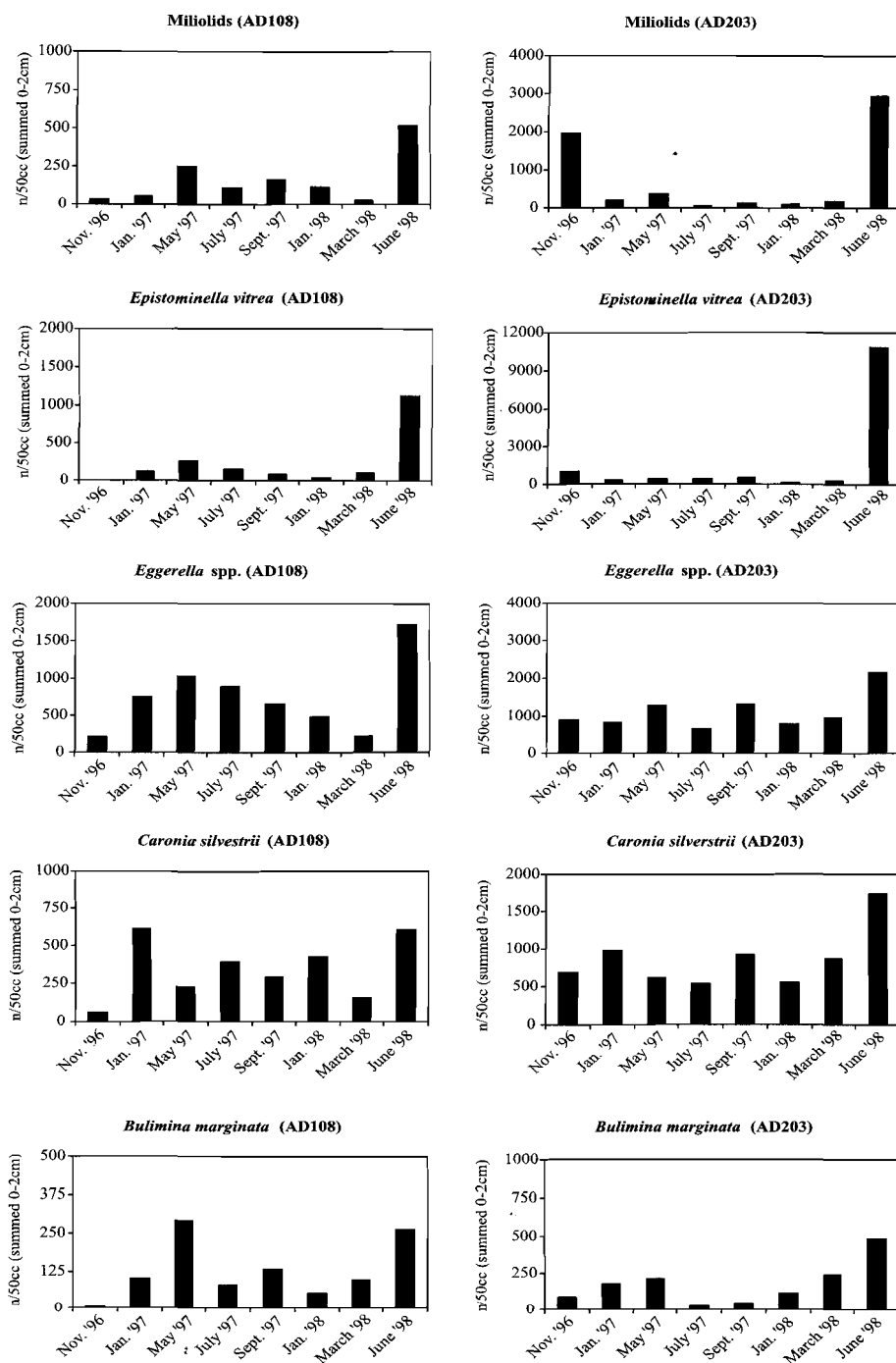
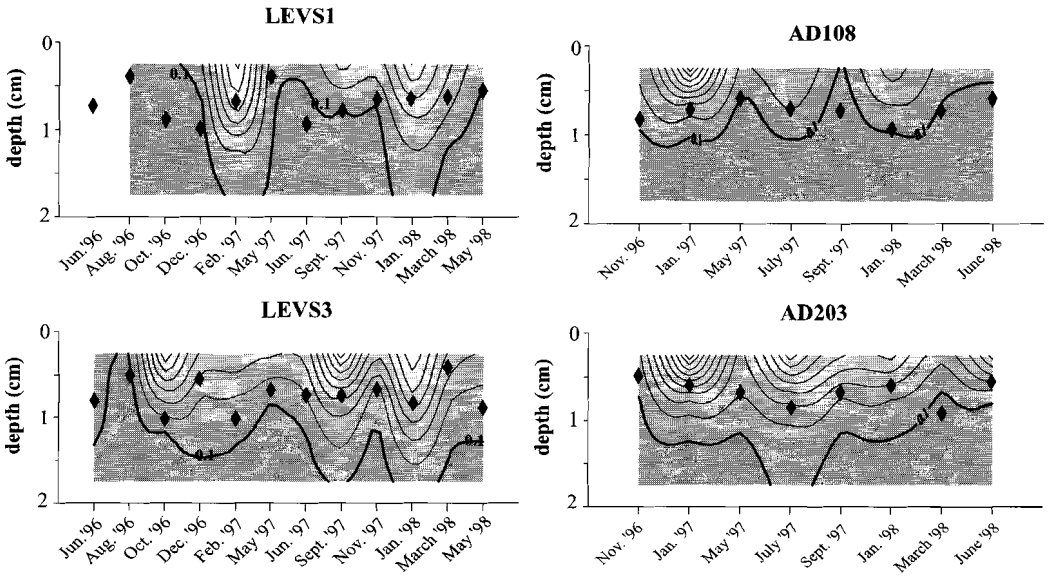


Figure 8-5: Total standing stocks (top 2cm; n/50cc) of the miliolids, *Epistominella vitrea*, *Eggerella* spp., *Caronia silvestrii*, and *Bulimina marginata* at the Levantine and the Adriatic stations.

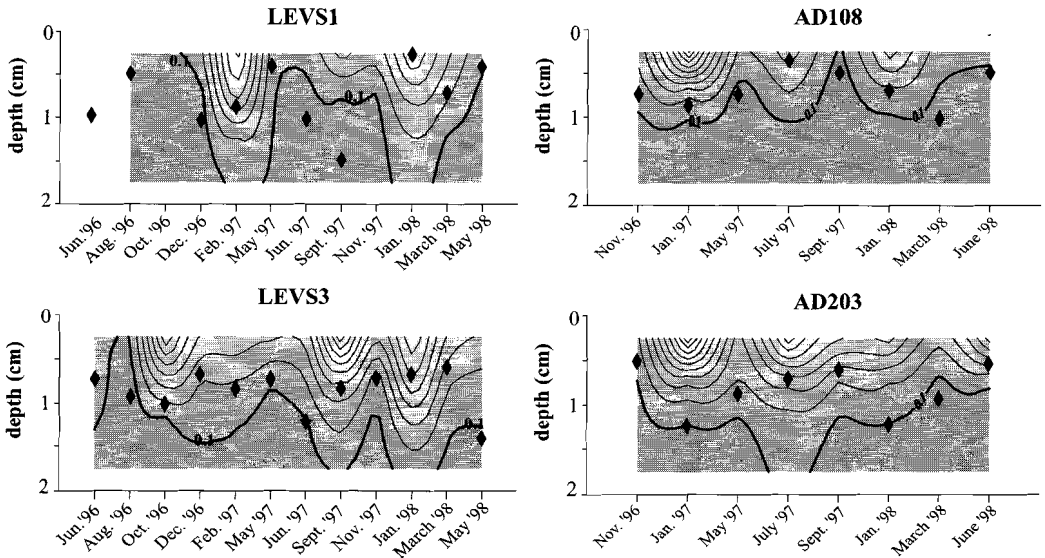
# Miliolids

a



# *Epistominella vitrea*

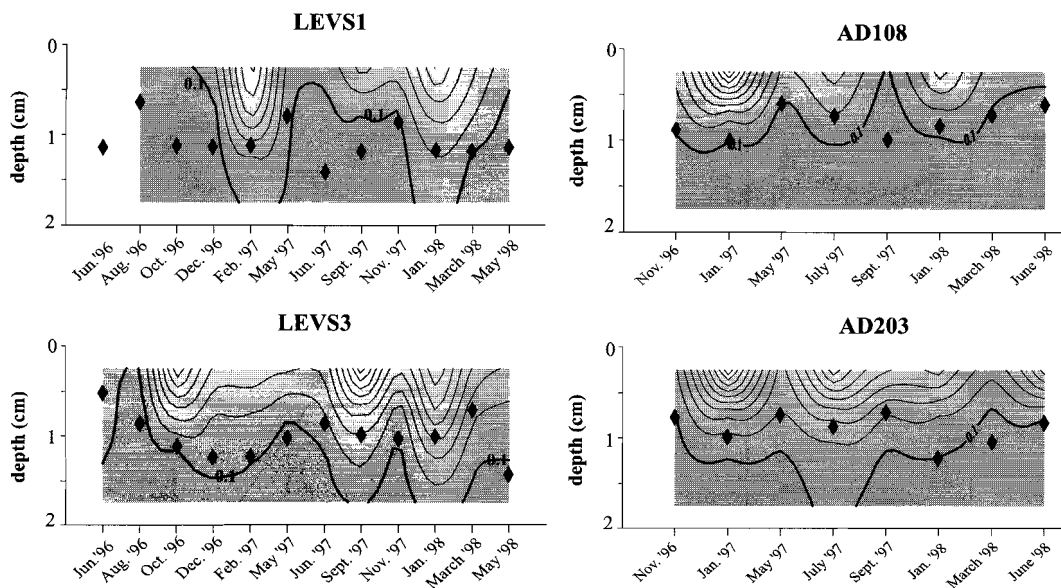
b



**Figure 8-6:** The ALD<sub>2</sub> of the miliolids and four common taxa at the four sample stations versus the occurring sediment oxygenation. a) miliolids; b) *Epistominella vitrea*; c) *Eggerella* spp.; d) *Caronia silvestrii*. The thick line indicates the level of 0.1ml/L oxygen, the ♦ symbols indicate the ALD<sub>2</sub>. At S1 no oxygen was measured in June '96.

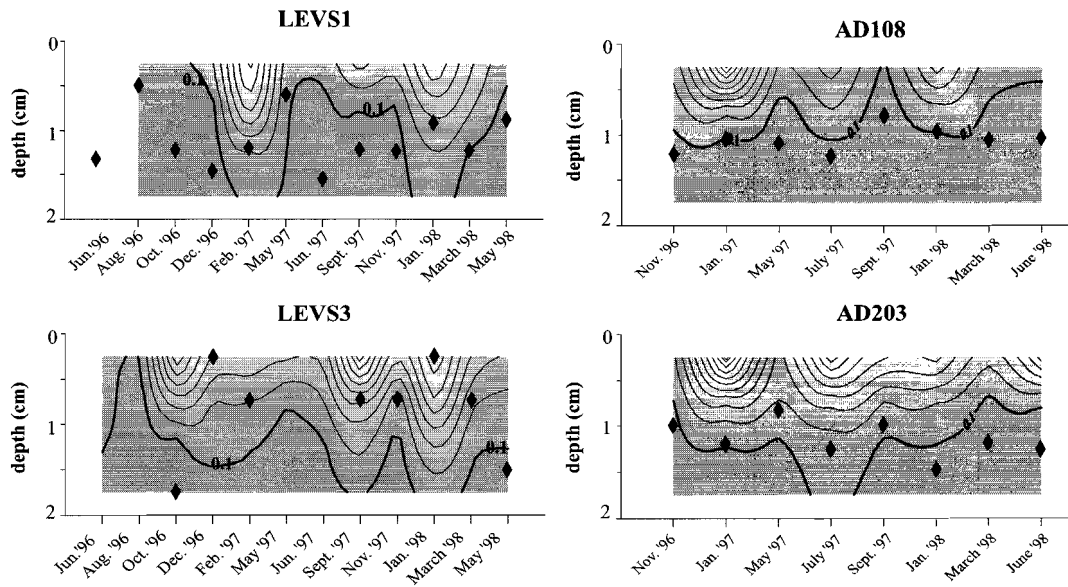
*Eggerella* spp.

c



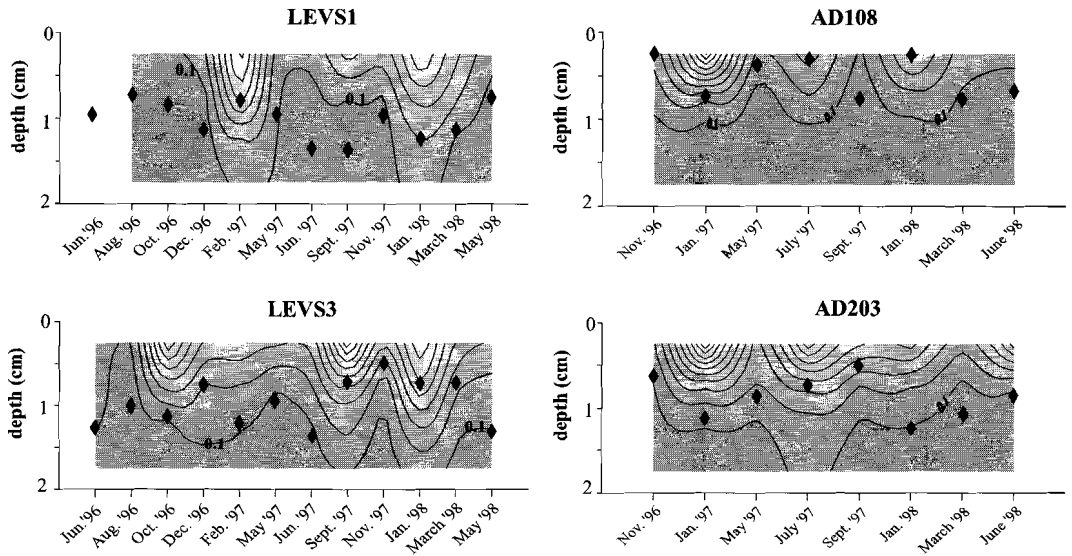
*Caronia silvestrii*

d



*Bulimina marginata*

e

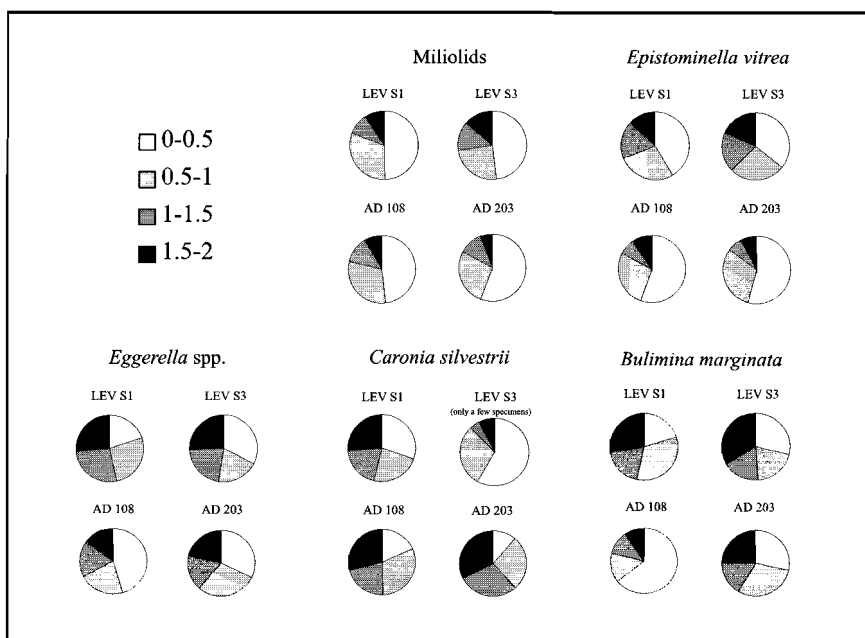


**Figure 8-6:** The  $ALD_2$  of the miliolids and four common taxa at the four sample stations versus the occurring sediment oxygenation. e) *Bulimina marginata*. The thick line indicates the level of 0.1 ml/L oxygen, the  $\blacklozenge$  symbols indicate the  $ALD_2$ . At S1 no oxygen was measured in June '96.

shallow (Fig. 6b). The  $ALD_2$ , as well as its relative abundance at all stations (except AD203) were not correlated with sediment oxygenation; it should be noted, however, that the species was only rarely found below the level of 0.1 ml/L oxygenation.

At station S1 the  $ALD_2$  of *Eggerella* spp. seasonally fluctuated considerably, between 0.5 cm and 1.5 cm, with no correlation to the sediment oxygenation (Fig. 6c). Its  $ALD_2$  at station S3 was less variable through time. At station AD108 and AD203 *Eggerella* occurred slightly shallower and showed less variation than in the Levantine stations. In none of the stations a correlation between the  $ALD_2$ , or the in-sediment abundance, versus oxygenation was found.

*Caronia silvestrii* appeared to be a rather deeply residing taxon (Fig. 6d); generally its  $ALD_2$  was found to be around 1 cm or deeper and only occasionally shallower than 0.75 cm (S1 and S3). At the Adriatic Sea sample stations its in-sediment distribution was more or less stable ( $ALD_2 \sim 1$  cm), whereas in the Levantine stations it changed drastically throughout the years. The vertical distribution of *C. silvestrii* over the sediment column at S3 is based on only a few specimens, which makes the  $ALD_2$  not reliable. No correlation was found between the  $ALD_2$ , and sediment oxygenation. The in-sediment abundance of this species was not correlated to the sediment oxygenation, except at AD108 where a negative correlation was found. This could very well be due to its preference for the deeper sediment layers. It should be noted that the  $ALD_2$  of *C. silvestrii* was often found to be below the level of 0.1 ml/L oxygenation.



**Figure 8-7:** The in-sediment distribution of the miliolids and four abundant taxa.

The  $ALD_2$  of *Bulimina marginata* displayed large fluctuations at all stations (Fig. 6e). At station S1 it was frequently well below the level of 0.1 ml/L oxygenation and also at S3 it was occasionally found below this level. At station AD108 the species occurred much shallower than at the Levantine stations, but also here the  $ALD_2$  was occasionally below the 0.1 ml/L oxygen level. The  $ALD_2$  of *B. marginata* at station AD203 was similar to that in the Levantine basin. As for the other species, no correlation existed between the sediment oxygenation and the  $ALD_2$ . Only at AD108 a positive correlation between its in-sediment distribution and sediment oxygenation was found.

The  $ALD_2$  of the five taxa exhibited a more fluctuating pattern at the Levantine stations than in the Adriatic stations. Except for the miliolids, for none of the five taxa a consistent correlation between the  $ALD_2$  or the in-sediment distribution patterns and sediment oxygenation was found.

### 3.5 Ecological niches

In figure 7, the two year averaged in-sediment distribution of the taxa over the top 2 cm is shown. The miliolids occurred, in the Levantine as well as in the Adriatic Sea, with 50% of their specimens in the topmost sediment layer and with 75% in the top 1cm. *Epistominella vitrea* was also most prominently living in the top cm of the substrate. In the Levantine, most specimens were found in 0-1cm (>60%); the remainder was equally spread out over the deeper sediment layers. In the Adriatic

Sea more than 80% of the living specimens were found in the top cm of the sediment, with the remaining specimens evenly distributed deeper.

*Eggerella* spp. is clearly a deeper living species, almost equally distributed over the top two cm sediment column. Only at site AD108 it showed a slight preference for the topmost sediment sample. Also *Caronia silvestrii* is occurring all over the sediment column. In the Adriatic sites it displayed a preference for the deeper sediment samples. The aberrant picture at site S3 was based on only a few specimens. The overall in-sediment distribution of *Bulimina marginata* is very similar to that of *Eggerella* spp., including the preference for the top sediment layer at site AD108.

## 4. Discussion

### 4.1 TSS patterns and biodiversity

Our data clearly demonstrate that diversity is highest in the most oligotrophic and stable area: the Levantine basin. We used simple diversity, because the data-sets are all based on approximately the same counting quantities. The high simple diversity as found in the Levantine basin can be related to stability, but more likely is that the less regularly occurring periods of severe stress play a prominent role (see for example Sanders, 1968). In the Levantine stations a large amount of taxa are rare, in contrast to most taxa in the Adriatic stations. One may assume that with stress, for instance related to anoxia as occurring in the Adriatic Sea, many rare species are eliminated. Following a period of stress, it apparently takes time to re-establish diversity at a high level (see also Sanders, 1968). This hypothesis finds some support if we look at the overall composition of the assemblages. The Adriatic samples are clearly characterised by a higher number of opportunistic species, whereas in the Levantine a rather large and sometimes highly diversified group of epifaunal and infaunal taxa dominates.

Although on the average the standing stocks in the Levantine Basin were lower than those in the Adriatic Sea, the TSS patterns displayed considerable fluctuations throughout the two years. In the Levantine station S1, they follow a rather clear seasonal cycle (see also Chapters 4 and 5). In station S3 the foraminiferal TSS increased during the first year in December '96 and during the second year in March '98, both times just after relative peak concentrations of chlorophyll-a (Chapter 6). At the shallow water Levantine site S1 no major factor next to the seasonal mixing of water layers in autumn and winter drives the marine system; this eventually results in a rather clear seasonal TSS pattern. The less clear-cut seasonal TSS pattern at station S3 is most likely due to much lower increase in food supply arriving here, resulting in less extreme numerical responses of the foraminifera. At this water depth additional food supply from the DCM is likely, which also could blur the seasonal cycle. Wollenburg & Kuhnt (2000) found that episodic supply of food was the critical environmental parameter influencing Arctic benthic foraminifera. In this overall low productive area they found maximum standing stocks during a phytoplankton bloom. But in our case apparently other factors interfere and lead to a somewhat blurred response of the TSS on the yearly productivity cycle.

At the Adriatic Sea stations, strong fluctuations in foraminiferal TSS throughout the years were found. The seasonal repetition here was even less obvious than at S3. This may be due to the fact that

sampling occurred rather irregularly, making it more difficult to keep track of seasonal changes. But even taking that into account, one has to acknowledge that the TSS pattern displayed no obvious (seasonal) repetition over the years. Especially the TSS pattern at station AD108 is characterised by large fluctuations. The high values in May '97 probably reflected organic enrichment of the sediment due to increased run-off, which is known to occur during spring (Jorissen et al., 1992). When water layers mix in autumn nutrients are brought up to the surface; also then increasing primary productivity eventually causes an increase in food supply at the sea floor. At station AD108 this was reflected in the high TSS in September '97 and at station AD203 high numbers of foraminifera were found in November '96 and September '97. Because station AD203 is located further from the Po-delta, the river run-off has less influence on the environmental circumstances at this station; this could explain why no clear peak in TSS was found during spring. The enormous peaks occurring in June '98 were aberrant and no clear explanation can be given for this. Considering that these peaks in foraminiferal TSS occurred simultaneously at both Adriatic stations, the obviously very profitable ecological circumstances occurred on a larger geographical scale.

In the highly eutrophic Sagami Bay, Kitazato et al. (2000) found the foraminiferal population size to be strongly driven by seasonal phytodetritus deposition. They suggest that seasonal flux is the most important determinant for population size. We have no reason to doubt this although in our case the correlation between flux and standing stock seems to be far more complex. The two different study areas are known to have completely different levels of trophication. However, the foraminiferal numbers found at stations S1 and AD203 were quite comparable. This suggests that the overall level of organic matter availability is not the major or only controlling factor. We assume that populations are limited also by stress. The latter is far more pronounced in the Adriatic Sea than in the Levantine, due to the regular anoxia events that occur over large areas. In this view the foraminiferal TSS would be decided by a delicate balance between food supply and stress.

#### 4.2 Standing stock patterns of the miliolids and four abundant taxa

The standing stock patterns of the miliolids and four foraminiferal taxa are overall very comparable for the four stations. The miliolids displayed numerical responses after increase of the organic matter load in the both the Adriatic Sea and the Levantine. The delayed numerical response of foraminifera living at station S1 is probably due to macrofaunal interference (extensively discussed in Chapters 4 and 5). At station S3 the miliolids reacted more directly to increased food supply and also in the Adriatic Sea the numerical responses of the miliolids seem related to times of organic enrichment. At station AD203 their standing stocks increased during autumn and spring of the first year, although in the second year no autumn peak was found. Overall, part of the life-strategy of the miliolid group seems to be to profit rather directly from increase in organic matter availability. This is even more pronounced in the case of *Epistominella vitrea*, that obviously profited during short periods from increased supply. Quick numerical response was also found for the deeper living counterpart of *E. vitrea*, *Epistominella exigua* which is known to occur abundantly after organic enrichment (Goody & Turley, 1990, Goody, 1988). As discussed by Goody (1993), this species is also able survive under

low trophic conditions but reproduces very opportunistically after food arrival on the seafloor. The same behaviour was found in the Arctic for *Epistominella arctica* by Wollenburg and Kuhnt (2000).

Surprisingly, also the standing stock patterns of *Eggerella* spp. and *Bulimina marginata* seemed to be controlled by increase of organic matter supply. This is less obvious for *Caronia silvestrii* that was far less abundant at station S3 than at the other stations. Our data suggest that even these deeper living taxa can respond rather promptly to organic matter enrichment. In many cases this seems to result in reproduction at the surface layer, where a higher proportion of the assemblage is then concentrated for some time (e.g. *Eggerella* spp., see Chapters 5 and 6).

### 4.3 Average living depth (ALD<sub>2</sub>) versus sediment oxygenation

At all four stations the ALD<sub>2</sub> of the miliolids was quite shallow. In the Levantine their ALD<sub>2</sub> fluctuated strongly, whereas in the Adriatic sediment it was more stable. At none of the stations there was a clear correlation between the ALD<sub>2</sub> of the miliolids and the sediment oxygenation. However, at all stations a significant positive correlation between their relative in-sediment distribution and sediment oxygenation was found. The fact that the ALD<sub>2</sub> is less sensitive to abundance patterns, explains why no clear correlations were found between ALD<sub>2</sub> and oxygenation. The deepest ALD<sub>2</sub> of the miliolids is found at times they occurred in relatively low numbers. The averaged standing stocks of miliolids, however, showed the clear tendency to live most abundantly in the shallowest sediment layers. The fact that this was found at all four stations, indicates that this epi- to shallow infaunal lifestyle is inherent to miliolids and not the result of local ecological conditions.

The ALD<sub>2</sub> of *Epistominella vitrea* fluctuated strongly at all stations, but showed no clear correlation with the sediment oxygenation. At S1 its ALD<sub>2</sub> displayed its most extreme fluctuations. As for the miliolids, the in-sediment standing stock distribution of *E. vitrea*, summarised over the years, suggests that the ecological niche it generally occupies within the sediment is a rather shallow one.

The other three taxa are obviously residing deeper in the sediment column. Also here, there seems to be a considerable similarity between the patterns from the different regions. *Eggerella* spp. had a relatively deeper ALD<sub>2</sub> than both the miliolids and *E. vitrea*, its ALD<sub>2</sub> being mostly deeper than 1 cm. Like *Eggerella* spp., *C. silvestrii* displayed relatively deep average living depths at all stations. Its in-sediment habitat is very similar to the one of *Eggerella* spp. *Bulimina marginata* was characterised by a relatively deep ALD<sub>2</sub> in the Levantine sediments, but in the sediments at AD108 it was found to be mostly rather shallow. The three deeper living (infaunal) species show less extreme fluctuations in their standing stock patterns through time than the more shallow living taxa. This could be due to the fact that the niche of the infaunal taxa is generally less crowded and that compared to the shallower sediment layers competition is less severe. Under conditions of sufficient food supply, there is probably no need to migrate to shallower sediment layers. Kitazato et al. (2000) also found deep infaunal foraminifera to generally show less pronounced seasonal fluctuations in population size. Nevertheless, even some of these deep infaunal taxa exhibited response to phytodetrital deposition. This is comparable to the pattern found for the deeper infaunal *Eggerella* spp., living very abundantly in the top sediment layer after organic enrichment. Afterwards, however, it was found to be dispersed



evenly again over the sediment column (see Chapters 5 and 6). This implies that it probably needs increased (fresh) organic matter supply in order to be triggered for reproduction. Its re-migration to deeper and less organic rich sediment layers might be caused by the much smaller foraminiferal densities here, which minimise competition stress.

It seems likely that the more shallow living taxa, that generally display more irregular TSS patterns, are somewhat more demanding with respect to food availability. Their relatively opportunistic life-style, e.g. quick numerical response after increased food availability, strengthens their competitive position and makes it possible for them to survive successfully in the shallow sediment layers. The positive correlation between miliolid abundance and oxygen implies that they are not able to thrive under oxygen deficient circumstances. This may force them to adopt a more epi- to shallow infaunal lifestyle in spite of the inherent relatively large competition stress.

## 5. Conclusions

The major factors controlling the foraminiferal standing stock patterns are (seasonal) organic matter enrichment and oxygen stress. The fact that foraminiferal numbers found in the Levantine basin were not much lower than those found in the Adriatic, suggests that standing stocks do not simply reflect the amount of organic flux, but probably more the balance between flux and limitation by stress. Diversity seems to be inversely related to average standing stock, possibly because quite a number of taxa occurring in low abundances are more easily eliminated by stress, resulting in low diversity but high standing stocks in the Adriatic Sea.

In spite of the differences between the Adriatic Sea and the Levantine Basin, five taxa that were studied in some detail occupied very constant microhabitat positions, suggesting that these are inherent to the species and not exclusively the result of the ambient in-sediment environment.

Whereas there was a significant correlation between the relative in-sediment distribution of miliolids and sediment oxygenation at both Levantine stations, no clear correlations were found for the ALD<sub>2</sub> versus oxygenation. For none of the other taxa a consistent correlation between in-sediment distribution and oxygenation was found.

Some deeper living taxa seemed to react on food supply by reproducing in the top sediment; after that, they re-migrated again in the deeper sediment layers. Epifaunal taxa reacted sharper to organic flux supply, but might experience stronger competition; this could be the cause of the more variable standing stock patterns over the years.

## Appendix 8-1

1= opportunists
2= epifaunal
3= shallow-deep infaunal

LEVS1	category	LEVS3	category
Acostata mariae	3	Acostata mariae	3
Adelosina spp.	2	Adelosina spp.	2
Ammobaculites spp.	2	Adercotryma glomerata	3
Ammodiscus sp.	3	aggl. milio	3
Ammonia spp.	1	Agglutinated (monoserial)	3
Ammoscalaria sp.	3	Ammodiscus sp.	3
Amphicoryna scalaris	3	Ammonia spp.	1
Anomalina globulosa	2	Ammoscalaria sp.	3
Astaculus sp.	2	Amphicoryna scalaris	3
Asterigerinata mamilla	2	Articulina sagra/tubulosa	2
Asteronion stelligerum	2	Astaculus sp.	2
Asterorotalia (Hottinger)	2	Asterigerinata mamilla	2
Biloculinella labiata	2	Asteronion stelligerum	2
Bolivid aggl. sp.	3	Asterorotalia (Hottinger)	2
Bolivina dilatata	3	Bigenerina nodosaria	2
Bolivina plicatella	3	Biloculinella labiata	2
Bolivina seminuda/spatulata	3	Bolivid aggl. sp.	3
Bolivina sp.	3	Bolivina alata	3
Bolivina striatula	3	Bolivina dilatata	3
Buccella granulata	2	Bolivina seminuda/spatulata	3
Bulimina aculeata	2	Bolivina sp.	3
Bulimina elongata	3	Bolivina striatula	3
Bulimina marginata	3	Bolivina subspinensis	3
Bulimina sp.	2	Bulimina elongata	3
Buliminella elegantissima	3	Bulimina marginata	3
Buliminella spp.	3	Bulimina striata	3
Caronia silvestrii	3	Buliminella elegantissima	3
Cassidulina carinata	2	Buliminella spp.	3
Cassidulina crassa	3	Caronia silvestrii	3
Cassidulina leavigata	2	Cassidulina carinata	2
Cassidulina subglobosa	2	Cassidulina crassa	3
Cibicides lobatulus	3	Cassidulina leavigata	2
Cornuspira sp.	2	Cassidulina subglobosa	2
Criboelphidium poeyanum	3	Cibicides lobatulus	3
Cribrostomoides sp.	3	Cornuspira sp.	2
Dentalina spp.	2	Criboelphidium poeyanum	3
Disconorbis bulbosus	2	Cribrostomoides sp.	3
Discorbinella rhodiensis	2	Dentalina spp.	2
Eggerella spp.	1	Discorbinella rhodiensis	2
Elphidium crispum	2	Eggerella spp.	1
Elphidium spp.	2	Epistominella vitrea	1
Epistominella vitrea	1	Fissurina sp.	3
Fursenkoina spp.	1	Fursenkoina spp.	1
Gavelinopsis preageri	2	Gavelinopsis preageri	2
Glomospira sp.1	3	Globobulimina pacifica	3

Appendix 8-1 (continued)

1= opportunists
2= epifaunal
3= shallow-deep infaunal

LEVS1	category	LEVS3	category
Gyroidinoides sp.	3	Glomospira sp.2 (geel)	3
Haplophragmoides spp.	3	Gyroidina sp.	3
Hopkinsina pacifica	1	Haplophragmoides spp.	3
Hyalinetriion sp.	2	Hopkinsina pacifica	1
Lagena striata	2	Hyalinetriion sp.	2
Lagenammina sp.	3	Lagena striata	2
Lenticulina peregrina	3	Lagenammina sp.	3
Lenticulina sp.	3	Lenticulina peregrina	3
Leptohalysis scotti	2	Lenticulina sp.	3
Melonis barleeaanum	3	Leptohalysis scotti	2
Miliolids (lump)	2	Liebusella goesi	2
monothalaam	2	Melonis barleeaanum	3
Nodophthalmidium sp.	2	Miliolids (lumb)	2
Nodosaria sp	2	Miliolinella sp.	2
Nonionella spp.	1	monothalaam	2
Planorbulina mediterraneensis	2	Neandrospira glomerata	3
Polymorphina sp.	2	Nodosaria sp	2
Porosonion granosum	3	Nonionella spp.	1
Quinqueloculina spp.	2	Nonionella turgida	1
Rectoglandulina rotundata	2	Planorbulina mediterraneensis	2
Rectouvirgerina cilindrica	2	Planulina araminensis	3
Reophax scoriurs	2	Polymorphina sp.	2
Reophax sp.	2	Pyrgo spp.	2
Reusella spinulosa	3	Quinqueloculina spp.	2
Rosalina floridensis/spp.	3	Rectouvirgerina cilindrica	2
Sigmoilopsis spp.	3	Reophax scoriurs	2
Soft-shelled saccaminids	3	Reophax spp.	2
Spiroloculina sp.	2	Reusella spinulosa	3
Stainforthia complanata	1	Robertinoides sp	3
Textularia agglutinans	3	Rosalina spp.	3
Textularia porrecta	3	Sigmoilopsis sp.	3
Trifarina spp.	3	Soft-shelled saccaminids	3
Trochaminna globi.	3	Spiroloculina sp.	2
Trochaminna inflata	3	Stainforthia complanata	1
Uvigerina meditt/semiornata	3	Svratkina sp.	3
Uvigerina sp.	3	Technitella legumen	2
Valvulineria bradyana	3	Textularia agglutinans	3
Valvulineria sp.	3	Textularia porrecta	3
		Textularia sp.	3
		Trifarina spp.	3
		Triloculina sp.	2
		Troch. glob.	3
		Trochaminna inflata	3
		Uvigerina mediterranea	3
		Uvigerina sp.	3

Appendix 8-1 (continued)

1= opportunists  
2= epifaunal  
3= shallow-deep infaunal

AD108	category	AD203	category
Acostata mariae	3	Acostata mariae	3
Adercotryna glomerata	3	allogromids	3
Ammodiscus spp.	3	Ammonia spp.	1
Ammoglobigerina globigeriniformis	3	Ammoscalaria pseudospiralis	3
Ammoscalaria pseudospiralis	3	Amphicoryna spp.	3
Amphicoryna spp.	3	Bolivina dilatata/spatulata/seminuda	3
Bolivina dilatata/spatulata/seminuda	3	Buccella granulata	2
Bulimina marginata	3	Bulimina marginata	3
Buliminella elegantissima	3	Buliminella elegantissima	3
Buliminella spp.	3	Buliminella spp.	3
Caronia silvestrii	3	Caronia silvestrii	3
Cassidulina crassa	3	Cassidulina crassa	3
Criboelphidium poeyanum	3	Cibicides lobatulus	3
Eggerella spp.	1	Criboelphidium poeyanum	3
Elphidium spp.	3	Eggerella spp.	1
Epistominella vitrea	1	Elphidium spp.	3
Fissurina spp.	3	Epistominella vitrea	1
Fursenkoina spp.	1	Fissurina spp.	3
Glomospira spp.	3	Fursenkoina spp.	1
Gyrogonoides spp.	3	Haplophragmoides spp.	3
Haplophragmoides spp.	3	Hopkinsina pacifica	1
Hopkinsina pacifica	1	Hyalinonetrix spp.	2
Lagena spp.	2	Lagena spp.	2
Lenticulina gibba	3	Lenticulina gibba	3
Leptohalysis scottii	2	Leptohalysis scottii	2
miliolids	2	miliolids	2
Nodosaria spp./Dentalina spp.	2	Nodosaria spp./Dentalina spp.	2
Nonionella turgida	1	Nonionella turgida	1
Nouria polymorphinoides	3	Nouria polymorphinoides	3
Oolina globosa	2	Oolina globosa	2
Polymorphina spp.	2	Planorbulina spp.	2
Porosonion granosum	3	Polymorphina spp.	2
Pseudoeponides falsobeccarii	2	Porosonion granosum	3
Reophax scorpiurus	2	Porosonion spp.	3
Reussella spinulosa	3	Pseudoeponides falsobeccarii	2
Rosalina bradyi	3	Reophax scorpiurus	2
Saccamina sp1.	3	Reussella spinulosa	3
Saccamina spp.	3	Rosalina bradyi	3
Sigmoilopsis schlumbergeri	3	Saccamina sp1.	3
soft-shelled Saccamina	3	Saccamina spp.	3
Stainforthia fusiformis	1	Sigmoilopsis schlumbergeri	3
Textularia agglutinans	3	Stainforthia fusiformis	1
Textularia porrecta	3	Textularia agglutinans	3
Textularia spp.	3	Textularia porrecta	3
Trifarina angulosa	3	Textularia sagittula	3