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Seasonal fouling by diatoms on artificial substrata at different depths near Piran (Gulf of Trieste, Northern Adriatic)

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Seasonal fouling by diatoms was studied in the heavily polluted and eutrofied area near Piran in the Gulf of Trieste. Concrete plates (50 x 50 cm) were placed at l m, 3 m and 7 m depths, with the fouling observed monthly for one year, from March to October. Two plates were used at each level: one was scratched clean monthly to get an insight into the seasonality of fouling, while from the other only representative samples were taken in order to follow the fouling succession. In the eulittoral two quadrats of the same dimension were scratched clean on a vertical concrete wall. Diatoms proved to be the main fouling component sublittorally, while in the eulittoral green algae determined the physiognomy of the experi mental surfaces during spring. The present contribution deals only with the diatoms. Peaks of diatom colonization were found in April and August in the eulittoral, and sublittorally in July. Regarding the depth distribution, maxima in the number of recorded species were found at 3 m in spring, and at 7 m in autumn. The fouling populations were heterogenous, including epilithic, epipsammic and epipelic species with different affinities (marine, brackish and even freshwater). Colonial forms belonging to the genera Berkeleya, Navicula *and* Licmophora *were outstanding and covered most of the experimental surfaces.* Achnanthes *species were among the primary colonizers, while* Nitzschia *species joined the fouling communities in autumn, along with several epipelic species. Seasonal recolonization on the monthly denuded plates was usual for species found sublittorally, either the whole year around, or only in autumn. Species found during spring did not recolonize monthly, and the same was true of the eulittoral ones.*

Key words: diatoms, depth distribution, seasonality, succession, fouling, artificial substrata, Northern Adriatic

INTRODUCTION

The importance of diatoms as primary colonizers on natural and artificial substrata was dealt already by SCHEER (1945), as well as later (e.g. HENDEY, 1951; CASTENHOLZ, 1963; NEUSHUL *et al*,. 1976; NIELL, 1979; SANTELICES *et al*., 1981; HUDON & BURGET, 1982; EDYVEAN *et al*., 1985; NIELL & VARELA, 1984; DELGARADO, 1989), along with a quantitative contribution by BLINN *et al.* (1980).

Diatoms respond sensitively and directly to chemical, physical and biological changes in the marine environment. Their use in ecological interpretations of pollution – and eutrophication induced changes was reported by SNOEIJS (1991), and several others.

The northern Adriatic (Fig. 1) is a shallow shelf area,with wide seasonal and interannual variations in temperature and salinity values, and a strong river runoff (ARTEGIANI *et al*., 1997). The Po river influences the formation of a peculiar circulation (ZORE-ARMANDA & VUČAK, 1984; ZORE-ARMANDA & GAČIĆ, 1987). In addition local circulations of a changing direction were noticed in the Gulf of Trieste (RAJER, 1990). In the heavily polluted and eutrofied area around Piran in the Gulf of Trieste profound changes in the benthic algal vegetation were observed, both in the eulittoral and sublittorally. There are also wide seasonal and annual variations in the vegetation pattrens. In connection with these pollution-and eutrophication induced changes interest arose about the initial stages of colonization on virgin substrata. Colonization was studied on submersed concrete plates and denuded eulittoral surfaces. The aim of the present study was to follow seasonal fouling and fouling succession at different depths.

In the eulittoral green algae and some seasonal floristic elements appeared on the denuded concrete surfaces;. sublittorally, however, diatoms were the main fouling component on the constantly submersed concrete plates.

Although phytoplankton distribution in the Adriatic Sea had been intensively investigated there are only few reports on the microphytobenthos, and dealing only with soft substrata (HERNDL *et al.,* l989; WELKER & NICHETTO, l996; FACCA *et al.,* 2002; TOTTI, 2003; TOLOMIO *et al.*, 2002; TOLOMIO, 2004).There are, on the other hand, no previous informations about diatom colonization on hard substrata in the Adriatic Sea.

MATERIAL AND METHODS

Concrete plates (50 x 50 cm and l0 cm thick) were exposed at the locality Punta Madonna near Piran (48º 32' N; l3º 34' E) at l m, 3 m and

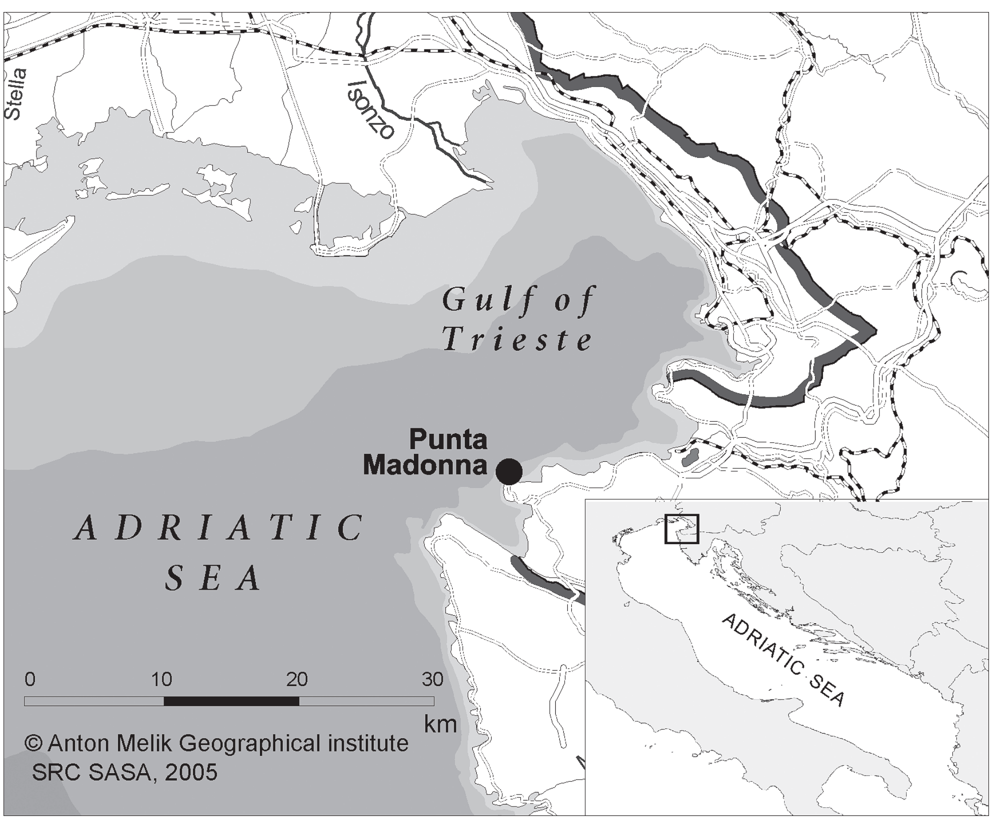


Fig. 1. Map of the area

7 m depths, in February.Two plates were placed at each level: one was scratched clean monthly, while from the other only representative samples were taken. In the eulittoral two quadrats were scratched clean on a vertical concrete wall, which surrounds a platform. The observations and samplings were carried out monthly during a one year period, from March to October. The degree of covering by fouling algae was determined roughly "*in situ*".

The collected material was preserved in 2.5% formaldehyde in seawater. A part of the algal material was determined immediately after sampling. Grosser elements of detritus were removed by straining through a small-mesh sieve. Samples were prepared following van der WERFF & HULS (1957-1974), by treatment with $H_2 0_2$ and $KMn0_4$, and were examined under a CARL ZEISS-AMPLIVAL light microscope.

For immediate species identification different floras were used, such as those of HUSTEDT (1913-1914 and 1927-1966), HENDEY (1964), and van der WERFF & HULS (1957-1974). Works of the Baltic water marine biologists were also consulted (e.g. SNOEIJS, 1993; SNOEIJS & VILBASTE, 1994; SNOEIJS & POTAPOVA, 1995). The nomenclature was updated according to HARTLEY (1986).

The greater part of the extensive diatom-containing samples was sent for further preparation and determinations to the following specialists: Mr. Hans van den HEUVEL, Leiden, and Dr. Paul HAMILTON, The National Museum of Canada, Ottawa. The diatom list presented here is based on their determinations and evaluations. It was later revised by Dr. Pauli SNOEIJS, Department of Ecological Botany, University of Uppsala.

The data obtained are synthetized in Table 4 in Appendix. A total of l35 species was recorded. For the relative abundance of the individual species an arbitrary scale was used following van den HEUVEL (cf. van den HEUVEL & PRUD'HOMME VAN REINE, 1985, van den HEUVEL, 1991) and myself. Species from the permanent (P) and the monthly cleaned quadrats (M) are treated separately. Water temperatures and salinities were measured simultaneously with algal samplings.

Ecological conditions and study area

The temperature and salinity data collected monthly during our field experiments, are presented in Table 1. In February/March the water temperature was still at its minimum, and increased with depth. In April, when the surface water temperature surpassed 11° C the opposite trend was found. In May, isothermic conditions occurred in the water column, and later (between June and August) during the summer stratificaton, a temperature decrease with depth.

Seasonal variations in salinity were opposite to those of the water temperature, with a minimum in June/July and maximum in February/March. There was a general trend of salinity increase with depth. The concentrations of

Table 1. Seasonal distribution of temperatures and salinities at different depths at Piran

Month	February	March	April	May	June	July	August	October	November
Depth (m)				temperature (° C)					
0	7.80	7.70	11.50	12.50	19.90	22.50	25.50	18.50	15.00
1	8.20	7.90	10.20	12.50	19.60	21.80	25.50	18.50	15.10
3	8.40	8.50	10.10	12.20	19.40	21.50	25.00	18.30	15.10
7	8.60	9.90	10.00	12.10	18.50	20.70	24.00	18.30	15.60
Depth (m)				salinity (psu)					
0	37.30	37.80	37.60	37.90	33.90	34.60	35.20	35.20	36.20
1	37.50	38.20	37.60	37.70	33.80	34.20	35.20	35.50	36.70
3	37.60	38.30	37.80	38.00	33.70	34.60	35.30	35.30	36.80
7	38.40	38.30	38.00	38.10	34.00	35.10	35.30	36.60	37.10

Table 2. Average values of primary nutrients in the surface water at Piran (µmol. L-1)

	PO4-P	NO3-N	NO2-N
January	0.24	4.13	0.99
February	0.27	3.08	0.28
March	0.25	2.19	0.15
April	0.12	1.88	0.09
May	0.06	1.86	0.01
June	0.03	0.53	0.06
July	0.01	0.31	0.01
August	0.02	0.21	0.01
October	0.28	2.30	0.04
November	0.31	4.39	0.04

primary nutrients, based on average values for the surface water at Piran are given in Table 2. A decrease in inorganic N and P was usual during summer, when phytoplankton blooms deplete the water of primary nutrients. According to TUŠNIK *et al*. (1989) the largest amount of nutrients is contributed to this area by sewage outflows from the town of Koper (204 and 42 t per year) for nitrogen and phosphorus respectively. Data based on measuremnts at the Marine Biological Station at Piran, however, indicated a decrease of inorganic nitrogen with depth and no definite trends for the phosphorus concentrations.

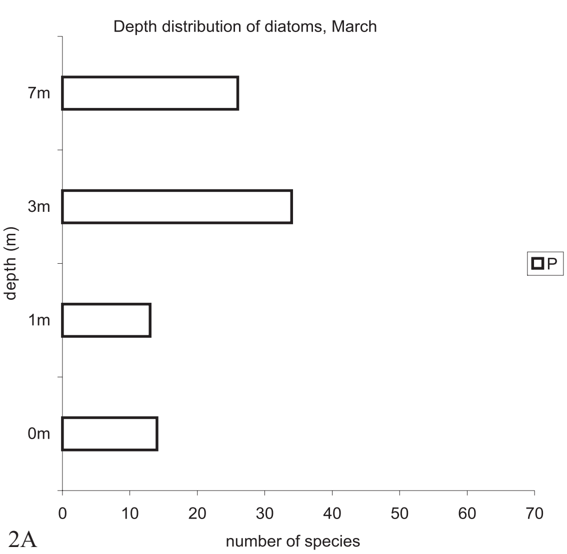
The locality Punta Madonna near Piran, where field experiments were carried out is situated in front of a north-east facing, heavily exposed concrete platform.The tidal range varies between 0.25 and l.20 m, and the eulittoral coincides with the vertical slopes of a concrete wall surrounding the platform. In the sublittoral there are bigger stones and rounded boulders, interrupted by sandy slopes. Hard substrata are found to about l0 m depth, from where continuous sandy slopes prevail.

RESULTS

A survey of the diatom species, recorded on the experimental surfaces during the seasons and at different depths, is presented in Table 4 in Appendix. Species from the permanently exposed (P) and the monthly cleaned plate (M) are presented separately.

Number of species

The number of recorded species, is presented in relation to depth (Fig. 2 a-g) and season (Fig. 3 a-d). In the eulittoral maxima in the number of species were found in April and August



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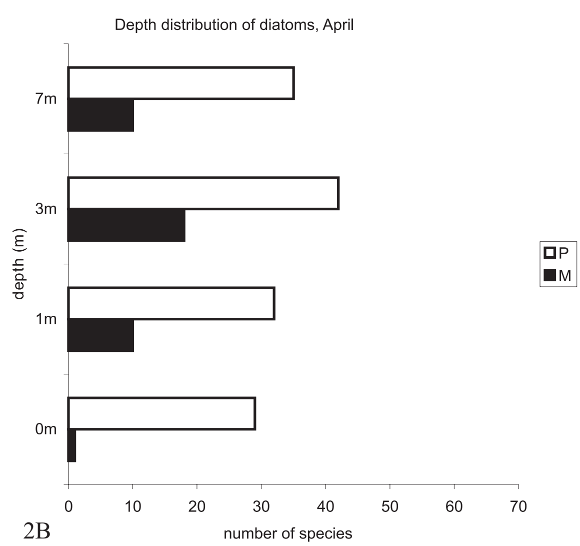

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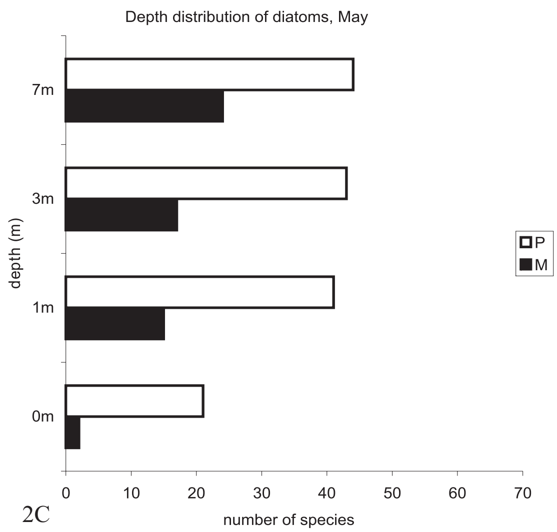

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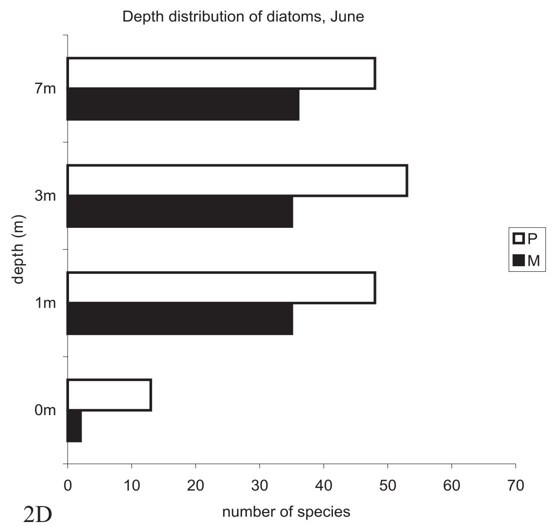

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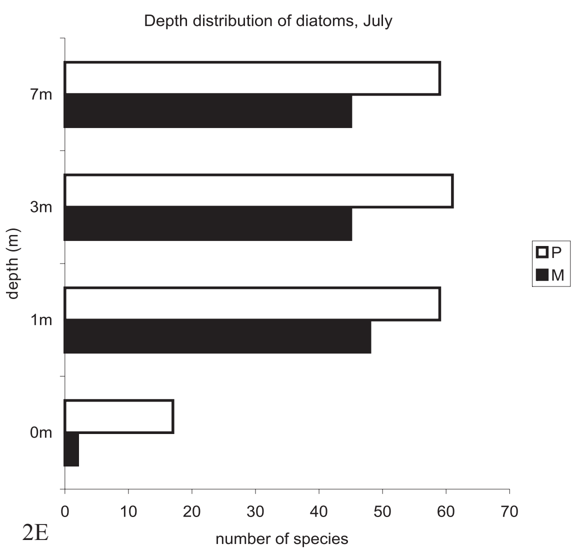

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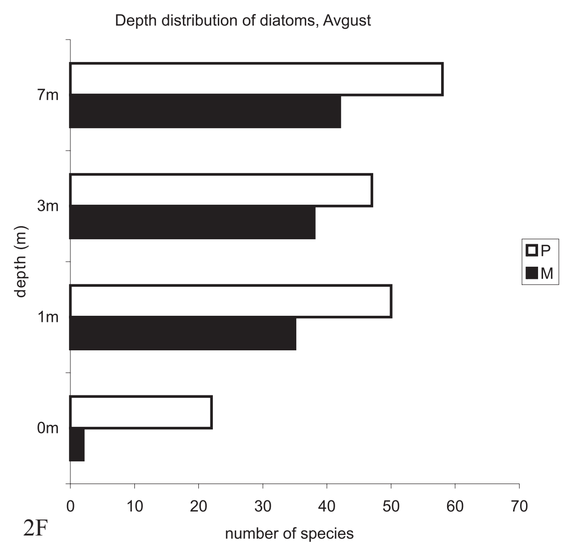

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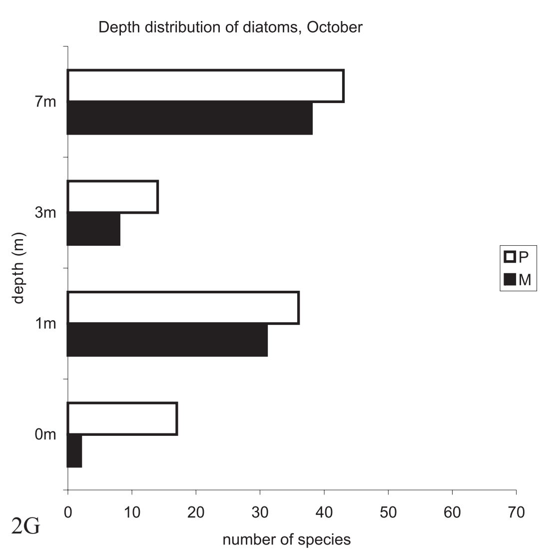

2G

Fig. 2. Depth distribution of diatoms: A-March, B-April, C-May, D-June, E-July, F-August, G-October; P-permanent plate, M- monthly cleane plate

(Fig. 3 a) on the permanent quadrat where also filamentous green algae were well represented. The number of diatom species on the monthly cleaned quadrat was negligible, and no seasonal variatons were obvious. Sublittorally, at l m and 3 m depths (Fig. 3 b, c) maxima in the number of colonizing diatom species were found in July. On the monthly denuded plate, less pronounced maxima were indicated in April as well, possibly due to an intensified recolonization in spring. At 7 m depth (Fig. 3 d) the maximum extended between July and August. The highest number of colonizing diatoms coincided, however, with the yearly temperature maxima and salinity minima.

The depth distribution of the number of recorded species (Fig. 2 a-g) exhibited some seasonal variations as well. A pronounced maximum at 3 m depth was found in March and April, and a rather uniform depth distribution between May and June during the time of isothermic conditions, as well as still in July. In autumn, between August and October, the maximum number of colonizing diatom species was found at 7 m depth. In all the cases the number of diatom species on the monthly denuded plates was lower than on the permanently exposed ones, indicating the degree of seasonal recolonization.

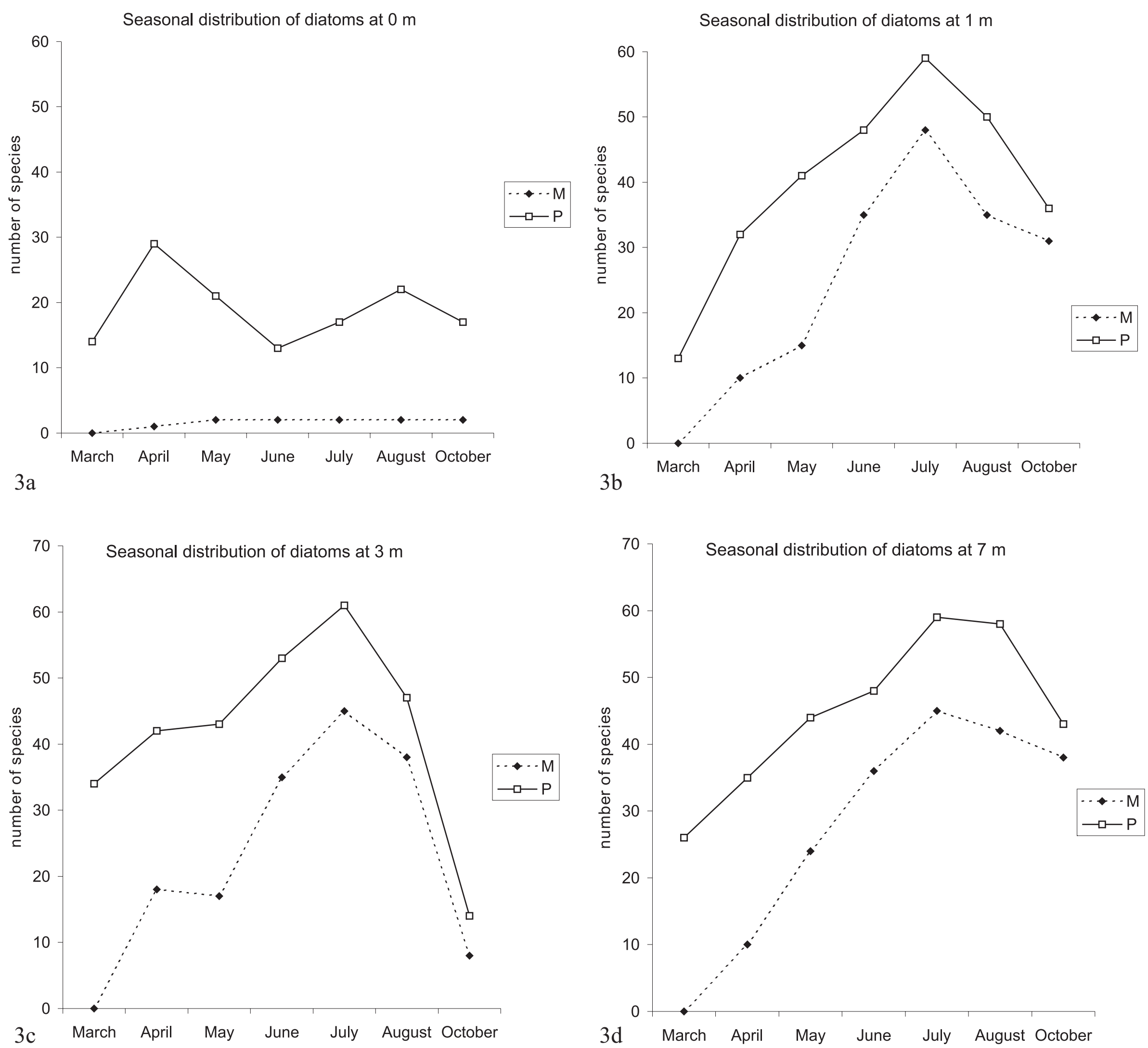

Fig. 3. Seasonal distribution of diatoms A-O m B- l m C- 3m D -7m; P-permanent plate M-monthly cleaned plate

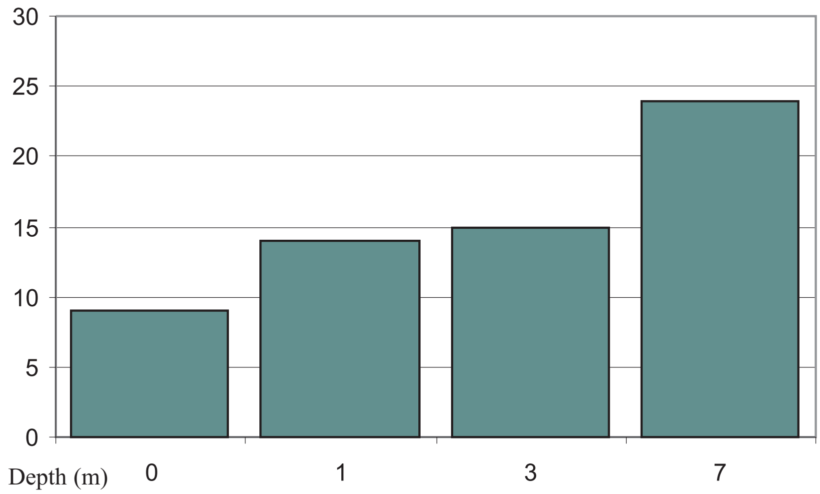

Fig. 4. Number of diatom species restricted to separate levels

In April about one half of the diatom species, present on the permanent plate, recolonized on the monthly cleaned one, with a maximum at 3 m depth. In May, when the number of diatoms was uniformely distributed according to depth, the highest monthly recolonization was observed at 7 m, indicating a vigorous spring colonization. The number of diatom species, which recolonized monthly, increased progressively towards the end of the year . The relation between the numbers of the permanently present and the monthly recolonized diatom species was closest in October. It is noteworhy, however, that a minimum in diatom colonization was found at 3 m depth due to environmental disturbances in October, viz. inundation of the experimental plates into the sand during autumn storms.

In general we could conclude that from the beginning to the end of the observation period the number of diatom species, which are able to recolonize on the monthly cleaned surfaces, came progressively closer to that of the permanent populations.

Some of the diatom species were restricted to separate levels (Fig. 4) and their number increased with depth. Most of the species were, however, found allthroughout the depths and seasons. The number of colonizing diatom species was the lowest eulittorally, where the seasonal course of colonization followed a different patern than in the sublittoral, with a minimum during the highest water temperatures.

Colonization by diatoms

Eulittoral

The denuded surfaces were recolonized already in March to an about 70% cover by green algae, among which diatoms were found epiphytic or epilithic. The most conspicuous were *Achnanthes brevipes*, *Cocconeis scutellum*, *C. costata*, *Licmophora abbreviata*, *L. paradoxa*, *Navicula ramosissima*, *Tabularia investiens*, *T. tabulata* and *Hyalosira delicatula*. In April, the fouling surface extended to 80% on the permanent quadrat. It was overgrown by the same green macroalgae, while the number of the fouling diatoms was nearly doubled. Beside the above mentioned species *Synedra laevigata* and *S. gaillonii* were the most prominent. Conspicuous were also *Podosira stelligera*, *Caloneis linearis*, *Navicula gibbula* and *Striatella unipunctata*. In May, the fouling surface was reduced to 60%, and macroalgal colonization was in decline. A further reduction, down to 30% occurred in June and July. *Achnanthes brevipes* was still outstanding among the diatoms, together with *Cocconeis scutellum*, *Tabularia investiens*, *Synedra gaillonii*, *Striatella unipunctata*, *Navicula ramosissima*. The number of the fouling diatom species was reduced. It increased again in August, when their community was enriched by several species, such as e.g. *Amphora coffeiformis*, *Cylindrotheca closterium*, *Grammatophora angulosa*, *Gyrosigma tenuissimum*, *Psammodyction panduriforme*, with *Berkeleya* and *Nitzschia* species as dominant. In October the number of colonizing diatom species decreased again. Conspicuous within the autumnal fouling community were *Berkeleya rutilans*, *Navicula ramosissima*, *Synedra laevigata*, *Striatella unipunctata* as well as *Nitzschia* sp. Most of the diatoms colonizing the eulittoral were found on the permanent quadrat only. On the monthly denuded one, seasonal fouling proved to be thus inconspicuous.

A few species were limited to the eulittoral and showed no seasonal recolonization: *Amphora pellucida*, *Achnanthes pseudogroenlandica*, *Caloneis fusioides*, *Cocconeis costata*, *Endyctia oceanica*, *Licmophora reichardii*, *Navicula gibbula*, *N. inflexa*, *Podosira stelligera* and *Synedra gaillonii.*

Sublittoral

In the eulittoral green algae determined the physiognomy of the experimental surfaces. In the sublittoral, on the contrast, diatoms were the main fouling component and macroalgae subordinate. The greater part of the sublittoral plates was covered by colonial forms in mucilage tubes or a polychotomously branched gelly matrix. Between April and July, however, *Berkeleya* species (*B. rutilans*, *B. micans*) covered the experimental surfaces as dominant at all the depths. *Achnanthes brevipes*, *A. longipes*, *Licmophora abbreviata*, *L. paradoxa*, *Striatella unipunctata*, *Cocconeis scutellum*, *Cylindrotheca closterium*, *Psammodyction panduriforme* and *Tabularia* species were conspicuous primary colonizers in the sublittoral. In April *Navicula ramosissima* appeared and became more abundant during the second half of the observation period. It formed up to l to 2 cm high polychotomously branched gelly colonies, and was beside *Berkeleya* species the main fouling component on the experimental surfaces.

Among the initial colonizers species with different ecological characteristics were found, mainly epilithic, potentially epiphytic, as well as epipelic and epipsammic ones. The usually epiphytic species were attached to the concrete surfaces by mucilage stalks or pads, or the solitary ones by the entire raphae surfaces.

1 m depth

At l m depth, the exposed concrete plates were covered initially by diatoms to about 30% of the entire surfaces. On the permanently exposed plate the % cover increased to l00% in April, and declined to 80% in May, followed by a renewed increase to l00% in June/July. It decreased again to 70% towards the end of the year (August, October).On the monthly denuded plate, the % cover resulting from seasonal fouling, was lower: with 50% in April, about 70% in May/June, 80% in July, 60% in August and only 30% in October.

At this depth, the concrete plates were covered by a mucous layer of colonial diatoms, within which *Berkeleya* species dominated in spring. Here they appeared later than at 3 m depth. The same was true for *Achnanthes brevipes*, *Amphora exigua* and the gelly colonies of *Navicula ramosissima*. The latter became outstanding during the second half of the year, when *Berkeleya* colonies were in decline. Conspicuous early colonizers (e.g. *Licmophora abbreviata*, *Entomoneis paludosa*, *Cylindrotheca closterium*, *Cocconeis scutellum*, *Striatella unipunctata*, *Synedra laevigata*, *Tabularia investiens*, *T.tabulata*) were shared with the eulittoral fouling community. Among the early colonizers, no notable differences between the permanent and the monthly cleaned plate were obvious, indicating seasonal fouling of all the species involved. During the second half of the observation period, *Nitzschia* species became abundant and outstanding. In October the number of the fouling diatom species was in decline.

At l m depth, some of the diatom species were found exclusively at this level: such as *Nitzschia distans*, *Amphora angusta*, *A. ovalis*, *Caloneis westii*. *Grammatophora hamulifera, Leptocylindrus danicus*, *Navicula fromenterae*, *Cocconeis distans*, *C.disculus*, *Licmophora hamulifera*, *Licmophora mediterranea*, *L. proboscioides*, *Synedra ehrenbergii*, *Navicula inflexa* and *Donkinia recta*.

3 m depth

There are only slight differences in the salinity and temperature regimes between l m and 3 m depths at Punta Madonna. Colonization on the exposed virgin surfaces was nevertheless more intensive here than at l m depth, starting with a l00% cover by diatoms in March, and remained as such towards the end of the observation period. In October, the fouling surfaces became damaged due to inundation into sand, caused by autumn storms.

On the monthly denuded plate the % cover decreased from the initial l00% in March, to 70% in April, and to 50% in May/June. It increased again to 70% during July and August.

The number of the colonizing diatom species was higher than at the l m level. For some species fouling started earlier than at l m (e.g. *Achnanthes brevipes*, *Amphora exigua*, *Berkeleya micans*, *B. fragilis*, *Licmophora ehrenbergii*, *Synedra laevigata*). In March the diatom cover was dominated by *Berkeleya*, *Achnanthes* and *Amphora* species, accompanied by *Bacillaria paxilifer*, *Cocconeis scutellum*, *Cylindrotheca closterium*, *Striatella unipunctata*, *Grammatophora* (*G. marina*, *G. oceanica*), *Licmophora* (*L. ehrenbergii*, *L. abbreviata*) and *Synedra* (*S. undulata*, *S. laevigata*) species.

Common among the primary colonizers were also *Thalassionema nitzschiodes*, *Trachyneis aspera* and *Tabulari*a species. In April, *Berkeleya* colonies covered the greater part of the experimental surfaces, and were still dominant in May and June. Outstanding at this time were also *Achnanthes brevipes*, *Licmophora paradoxa*, *Navicula cryptocepthala*, *N. reversa*, *Psammodictyon panduriforme*, *Striatella unipunctata* and *Tabularia* species.In July the diatom cover became dominated by *Navicula ramosissima* colonies, along with diverse *Nitzschia* species. Between May and July the number of the fouling diatom species was similar at l m and 3 m depths, while in March and April, maxima at 3 m were obvious. For most of the species, however, a seasonal recolonization on the monthly denuded plate was observed.

A few of the species proved to be limited to the 3 m depth, such as *Achnanthes bremeyeri*, *Amphora costata*, *A. decussata*, *Anaulus balticus*, *Auricula minuta*, *Cocconeis pediculus*, *Entomoneis alata*, *E. gigantea*, *Grammatophora marina*, *Stauroneis* sp., *Synedra berolinensis*, *S. hennedyana*, *Caloneis liber* and *Tryblionella alata*.

7 m depth

At a 7 m depth a rather irregular seasonal distribution of diatoms was observed, with a maximum number between July and August. The first stages of colonization were similar as at 3 m depth, with a dominance of *Berkeleya* colonies of 90% cover. Among the initial colonizers *Synedra laevigata* was outstanding, and accompanied by *S. undulata*, *Tabularia* species, *Amphora exigua, Licmophora abbreviata, Cocconeis scutellum, Navicula salinicula, N. pseudohybrida, Striatella unipunctata and Psammodictyon panduriforme.* In April the % cover declined to 50% on the permanent and to 30% on the monthly cleaned plate. In May, it increased again to l00% and to 90% respectively. On the permanently exposed one, the % cover declined to 60 in June/July and increased again to l00 August. On the monthly cleaned plate, the % cover was only 50 in June, 70 in July and again l00 in August. In October it dropped to 30%. All these irregular fluctuations in the % cover were first of all due to the simultaneous macroalgal colonization.

Berkeleya colonies, which were the main fouling component initially, declined already in July, to be replaced by *Navicula ramosissima* ones. The latter were more frequent here than at l m and 3 m depths, and dominant during the second half of the year, when also *Amphora* species were well represented (*A. coffeiformis*, *A. binodis*, *A. binodulata*, *A. acutiuscula*), along with diverse *Diploneis* and *Cocconeis* species.

In autumn, maxima in the number of recorded species were transferred from 3 to 7 m depth. Among the total of recorded species 24 were found only here : *Amphora binodulata*, *A. ocellata*, *Actinocyclus octonarius*, (a freshwater species), *Cocconeis diminuta*, *C. peltoides*, *Dimerogramma minor*, *Coscinodiscus* sp., *Diploneis littoralis*, *D. oculata*, *D. vacillans*, *Paralia sulcata*, *Hemiaulus hauckii*, *Fallacia forcipata*, *Opephora olsenii*, *Mastogloia apiculata*, *M. quinquecostata*, *Navicula directa*, *N. palpeblepharis*, *Staurosira decipiens*, *Staurosirella pinnata*, *Thalasiosira rotula*, *Thalasiothrix frauenfeldii*, *Trachysphaenia australis* and *Tabularia fenestrata* (a further freshwater species). Monthly recolonization was usual for most of the species at this depth.

At 7 m depth, the exposed concrete plates were close to the sublittoral sandy slopes, and on the lower limit of the hard substrata and of the bentic algal vegetation. This situation is tentatively responsible for the irregular seasonal fluctuations in the degree of cover, increased proportion of epipelic and epipsammic species in the fouling community, and for the lag periods in the appearance of some diatoms.

Seasonal distribution and succession

Some of the diatom species, recorded during the present experiments were found throughout the whole year, while most at them exhibited an uneven, scattered distributional pattern. Several species were found as initial colonizers during spring, but most of them appeared during the second half of the year, when epipelic ones dominated.

Characteristic summer and autumn species were: *Anaulus balticus*, *Achnantes bremeyeri*, *Cocconeis disculus*, *Amphora* species (*A. binodis*, *A. ovalis*, *A. coffeiformis*, *A. acutiuscula*, *A. decussata*, *A. pellucida*, *A. costata*), *Caloneis liber*, *C. westii*, *Diploneis splendida*, *D. oculata*, *Gyrosigma tenuissimum*, diverse *Nitzschia* species, *Haslea ostrearia*, *Hemiaulus hauckii*, *Rhopalodia operculata*, *Raphoneis amphiceros*, *Stauroneis decipiens*, *Synedra* species (*S. fulgens*, *S. toxonoides*, *S. hennedyana*), *Entomoneis gigantea*, *Thalassiosira rotula*, *Thalassiothrix frauenfeldii*, *Trachisphaenia australis*, *Tryblionella debilis*. Most of these autumnal species exibited seasonal recolonization on the monthly denuded plates, with only a few exceptions, such as *Tryblionella debilis*, *Trachisphaenia australis*, *Caloneis liber*, *C. westii*, *Nitzschia dissipata*, *Synedra hennedyana*, *Entomoneis gigantea*, *Thalassiosira rotula*.

During the first half of the year, between March and June, fewer species were observed. Some were among the initial colonizers, such as *Licmophora hyalina*, *L. mediterranea*, *L. reichardii*, *Auricula minuta*, *Bacillaria paxilifer*, *Cocconeis distans*, *C.peltoides*, *Dimerogramma minor*, *Diploneis vacillans*, *Falacia forcipata*, *Endyctia oceanica*, *Hyalosira delicatula*, *Navicula salinicola*, *N. directa*, *N. fromenterae*, *N. gibbula*, *Nitzschia valdestriata*, *N. pseudohybrida*, *Paralia sulcata*, *Podosira stelligera*, *Grammatophora marina*, *Ditylum brightwellii*, *Synedra berolinensis*, *S. ehrenbergii*. All the vernal species, in contrast to the autumnal ones, did not recolonize on the monthly denuded plates. They appeared succeedingly, but lacked the ability of seasonal recolonization. The only exceptions were *Navicula salinicola* and *Bacillaria paxillifer*.

Some of the initial colonizers were found throughout the entire observtion period, from March to October, on both plates. These species included several epilithic colonial forms, which covered most of the disponible experimental surfaces. Noteworthy are *Berkeleya* species (*B. rutilans*, *B. micans*, *B. fragilis*), *Achnanthes brevipes*, *A. longipes*, *Amphora marina*, *A. exigua* *Cocconeis scutellum*, *Cylindrotheca closterium*, *Licmophora abbreviata*, *L. paradoxa*, *Navicula ramosisima*, *Striatella unipunctata*, *Tabularia tabulata*, *T. investiens*, *Entomoneis paludosa*, *Nitzschia reversa*, *Synedra laevigata*, *S. undulata* and *Psammodictyon panduriforme*. Among these common diatoms some are functionally epiphytic, such as *Synedra*, *Achnanthes*, *Tabula-*

ria and *Licmophora* species, but were found as epilithic on the experimental surfaces. Most of these dominant colonizing diatoms are cosmopolitic, mesohaline and found also in eutrofied habitats of harbours..

Diatom colonization on exposed concrete surfaces had revealed, however, that colonial forms in mucilage tubes or in a branched gelly matrix (*Berkeleya* species, *Navicula ramosissima*) were dominant in the fouling community. Results indicated, that common species found throughout the whole year, recolonized monthly on the denuded plates and thus exhibited a pronounced seasonality. The same was true of species which joined during the second half of the year. Among them epipelic forms prevailed. Only a few did not recolonize monthly. During the first half of the year, on the other hand, colonial epilithic species dominated; they appeared succeedingly, but showed no seasonal recolonization. (Table 3.)

DISCUSSION AND CONCLUSIONS

Colonization on artificial substrata and denuded rocky surfaces was studied in different areas (HENDEY, 1951; HUVĖ, 1969; MARGALEF, 1969; KAIN, 1975; BELANGER & CARDINAL, 1977; MCINTIRE & MOORE, 1977; EMERSON & ZEDLER, 1978; MURRAY & LITTLER, 1978; GORĖN, 1979; MUNDA, 1977; MARKHAM & MUNDA, 1980; HAWKINS, 1981; CHALMER, 1982; NIELL, 1979; NIELL & VARELA, 1984; BADALAMENTI *et al*., 1984; RIGGIO, *et al.* 1985; MCLULICH, 1986, 1987; FERNANDEZ & MIYARES, 1989; FALCIATORE, 2000). It is a complex process and depends on seasonal aspects of the neighbouring vegetation, abiotic factors along with succession in a developing community. Diatoms are usually the primary colonizers at all the littoral levels. They are sensitive to air exposure, and their occurrence in the eulittoral depends on the severity of the aerial environment (CASTENHOLZ, 1963; BELANGER & CARDINAL, 1977; MCLULICH, 1987). Our experiments proved, however, that the number of colonizing diatoms was notably lower in the eulittoral than in the sublittoral. No recolonization on the monthly denuded quadrats was found.There was, however, no seasonal appearence, only succession on the permanetly exposed ones.

In the sublittoral diatoms were the main colonizers on the virgin surfaces, and most of them recolonized monthly, after the fouling community had been removed. This was first of all true for those diatom species which were found during the whole year or only in autumn, while monthly recolonization was only exceptional for spring species.

The number of the diatom species recorded on the virgin surfaces reflects colonization by settlement, invading of motile diatoms from the surrounding rocks or sand-flates, as well as reproduction. Pelagic species can also be trapped onto the experimental surfaces.

In the eulittoral, the seasonal course of the number of diatom species exhibited two peaks, in April and in August, while sublitorally the number of species increased progressively from March to July, and declined again in autumn. This was in accord with observations reported by ROUND (1972, 1985), who found the highest number of diatom species during periods of the maximum irradiance and temperature.

The diatom communities were characterised by epilithic colonial forms belonging to the genera *Berkeleya*, *Navicula*, *Achnanthes* and *Licmophora*. Tube - dwelling diatoms were the main fouling component during our experiments with *Berkeleya rutilans* and *B. micans* as dominants (cf. DRUM, 1969; COX, 1975, 1977; LOBBAN,

Table 3. Degree of seasonal recolonization

	number of species	% recolonization
species present the whole year	20	100
species found in summer/autumn	32	95
species found in spring	24	0

1984; CHASTAIN & STEWART, 1985). Both species are common and widely distributed at different habitats along the Mediterranean and Atlantic coasts of Europe and represent the “metaphyton“ *sensu* ROUND (1985). They covered the greater part of the exposed concrete plates, mostly in spring, but were present throughout the whole year. During the second half of the year, differently shaped gelly colonies, up to 1 to 2 cm high and polychotomously branched, dominated. They contained *Navicula ramosissima* and *N*. sp. Beside, a high abundance of different *Nitzschia* species was characteristic of the autumnal vegetation.

Epilithic species, found initially during spring, were followed by epipelic and epipsammic ones later during the year, when sand grains accumulate on the plates. Noteworthy are in particular several *Amphora* species, which are able of rapid recolonization. SUNDBÄCK & SNOEIJS (1991) likewise observed a predominance of *Nitzschia* and *Amphora* species on sandy substrata of the Swedish coast. LESKINEN & HÄLLFORS (1990) found a high abundance of *Nitzschia* species in the Gulf of Finland and considered them as indicators of eutrophic conditions.

Living diatom communities can be used as tools for environmental changes and gradients (SNOEIJS, 1991; BUSSE & SNOEIJS, 2002, 2003), and can also reflect eutrophication (HILLEBRAND & SOMMER, 1997, 2000; ANDRÉN, 1999; AGATZ *et al.*, 1999; WELKER *et al.*, 2002). The Gulf of Trieste is heavily polluted and eutrofied as a whole. Along its eastern area eutrophication originates first of all from a heavy load of domestic sewage, due to urbanization and tourism (FAGANELI & TUŠNIK, 1983; DEGOBBIS, 1989; DEGOBBIS & GILMARTIN, 1990). Nevertheless relatively low concentrations of macronutrients were detected around Piran during our field studies.

Diatoms can also be classified according their salinity tolerance (e.g. SNOEIJS, 1993; SNOEIJS & VILBASTE, 1994; SNOEIJS & POTAPOVA, 1995). In our material there was a wide spectrum of ecologically different types, with marine, brackish and even freshwater affinities. Most of the species proved to be euryhaline, and widely distributed in different habitats. They have as such a competitive advantage among the colonizing species, but cannot be regarded as environmental indicators of eutrophication or of perturbated environments in general.

Among conspicuous primary colonizers were, beside *Berkeleya*, also *Achnanthes* species, which form dense epilithic populations, due to their attachment by stalks. *Achnanthes brevipes*, a common estuarine species, found frequently in harbours, colonized the experimental surfaces at all the levels, while *A. longipes* did not occur eulitorally (HENDEY, 1951; ROUND, 1971; LANGE-BERTALOT & KRAMER, 1989; LEWIS *et al.,* 2002). Further conspicuous primary colonizers were *Licmophora* species, first of all *L. abbreviata* and *L. paradoxa*. *Cocconeis scutellum* and *Striatella unipunctata* were extremely abundant throughout the entire observation period at all the levels. Noteworthy is also the centric diatom *Paralia sulcata*, which is regarded as an indicator species of coastal upwelling situations. It appears both in the plankton and the benthos, and has a competitive advantage under low light conditions (MARGALEF, 1969; ZONG, 1997; MCQUOID & NORDBERG, 2003). In accordance to this, it was found only at 7 m depth, where it did not recolonize monthly.

During the present experiments attention was focused, however, on the spatio-temporal dynamics of the fouling communities. The relations between micro- and macrophytobenthos were considered separately (cf. MUNDA, 1977, 1991). Our sampling strategy was defined to compare two parameters: depth and season, with regard to the different patterns of succession in diatom colonization. There was a variability in colonizing events related to depth; and difference between the trends of diatom and macroalgal colonization. It was obvious that diatoms have advantage towards the macrophytobenthos regarding colonization of sublittoral virgin surfaceas.They are less successive in the eulittoral, where ephemeral macroalgae seasonally dominate, especially during spring. In the sublittoral, on the other hand, diatoms were the main fouling component and macroalgae in minority.

There were also differences in the trends of macroalgal and diatom colonization related to depth (MUNDA, 1991). As contrast to the macroalgae, some of the diatoms appeared earlier at 3 m and 7 m than at l m and/or eulittorally, as for example *Bacillaria paxillifer*, *Berkeleya micans*, *B. rutilans*, *B. fragilis*, *Climatoneis inflexa*, *Cocconeis molesta*, *Entomoneis paludosa*, *Licmophora ehrenbergii*, *L. hyalina*, *Navicula ramosissima*, *Synedra laevigata* and *Trachyneis aspera*. *Cocconeis molesta*, in particular, exhibited a clear lag period related to depth, appearing at l m in July, at 3 m in June and at 7 m in May, while it was absent eulittorally.

The sequences of events during succession and seasonal recolonization were thus different for the diatoms and the macroalgae. In spite of an improved macroalgal colonization during the second half of the year (MUNDA, 1991) their fouling communities did not yet reagain the taxonomic composition and physiognomy of the neighbouring sublittoral vegetation. This might indicate adverse ecological conditions for macroalgae, and more favourable ones for the development of diatom populations, which frequently interrupt the macrophytobenthos in this particular area.

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SAŽETAK

Proučavan je sezonski obraštaj dijatomeja u vrlo zagađenoj i eutrofiziranoj sredini u blizini Pirana u Tršćanskom zaljevu. Betonske ploče (50 x 50 cm) su bile postavljene na dubinama od 1, 3 i 7 metara, kako bi se promatralo mjesečno obraštanje (od ožujka do listopada) tijekom godine. Od dvije ploče, jedna je ostrugana mjesečno kako bi se dobio uvid u sezonsko obraštanje, dok su s druge uzimani samo reprezentativni uzorci zbog promatranja sezonske sukcesije obraštanja. U eulitoralu su dva četverokuta istih dimenzija struganjem očišćena s vertikalne stijenke. Utvrđeno je da su dijatomeje glavna komponenta obraštaja u sublitoralu, dok u eulitoralu zelene alge određuju fizionomiju eksperimentalnih površina tijekom proljeća. Ovaj rad se odnosi samo na dijatomeje. Najjače naseljavanje dijatomeja je zapaženo u travnju i kolovozu u području eulitorala, a u subliteralu u srpnju. S obzirom na dubinsku raspodjelu vrsta, najveći broj je zabilježen na dubini od 3 metra u proljeće i na dubini od 7 m u jesen. Obraštajne populacije su bile heterogene, uključujući vrste koje žive na stjenovitoj, pješčanoj i muljevitoj podlozi i različitih su sklonosti (morske, bočatne i čak slatkovodne). Najistaknutiji su bili kolonijski oblici koji su pripadali rodovima *Berkeleya*, *Navicula* i *Licmophora*, pokrivajući najveći dio eksperimentalnih površina. Kao prve su se naseljavale vrste roda *Achnanthes*, dok su se vrste roda *Nitzschia* u obraštajnim zajednicama pojavile u jesen zajedno s nekolicinom vrsta muljevitih dna. Sezonska rekolonizacija na ogoljenim pločama bila je uobičajena za vrste nađene u sublitoralu, bilo tijekom cijele godine ili samo u jesen. Vrste nađene u proljeće nisu se ponovo naseljavale mjesečno, što vrijedi i za eulitoralne vrste.

Ključne riječi: dijatomeje, dubinska raspodjela, sezonsko kretanje, obraštaj, umjetni supstrat, sjeverni Jadran

APPENDIX

Table 4. Seasonal and depth distribution of diatoms on the experimental plates (see legend at the end of the table)

Bacilllariophyceae - Diatoms

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
Achnanthes bremeyeri Lange-Bertalot	0m														
	1m														
	3m										RR		R		
	7m														
A. brevipes C. Ag.	0m				A		R		A		A		R		M
	1m			R	R	R	A	R	A				R		
	3m		R	R	RR		RR	R	R	M	M	R	R		
	7m												A	R	R
A. brevipes var. *intermedia* (Kütz.) Cleve	0m		S		A										
	1m							RR	R				R		A
	3m		RR		RR		RR		R						
	7m														
A. longipes C. Ag	0m														
	1m		RR	RR	RR	R	RR			RR	RR		R	A	A
	3m		RR		RR		RR			RR	M				
	7m				RR				R		R			RR	R
A. pseudogroen-landica Hendey	0m		S		R		R								
	1m														
	3m														
	7m														
A. sp.	0m														
	1m							RR	R						
	3m							RR							
	7m						RR								
Actinocylus oct-onarius (W. Smith) Hendey	0m														
	1m														
	3m														
	7m				RR	RR	RR								
Amphora acutiusc-ula Kütz.	0m														
	1m														
	3m											RR	R		
	7m									RR	RR	R	RR		
A. angusta Greg.	0m														
	1m										RR		RR		
	3m														
	7m														
A. binodis Greg.	0m														
	1m														
	3m													RR	R
	7m											RR	R	RR	R
A. binodulata (Bernard) Therriault & Cardinal	0m														
	1m														
	3m														
	7m												RR	RR	RR
A. coffeaeformis (C. Ag.) Kütz.	0m								R		R		R		A
	1m							R	D	R	R			R	R
	3m							R	R						
	7m							R	R			A	A	R	R
A. costata W. Smith	0m														
	1m														
	3m									RR	RR				
	7m														
A. decussata Grun.	0m														
	1m														
	3m									RR	RR	RR	R		
	7m														
A. exigua Greg.	0m				R										R
	1m				R	R	RR	R	R	A	R	A	A	RR	A
	3m		R		R		M		R	R	M	D			
	7m		R		R	RR	R	M	R	RR	A	RR	A	A	D
A. hyalina Kütz.	0m										R				
	1m						R	R	R	D	R	A	A	RR	R
	3m							RR	R	A	A	A	A		
	7m				RR			RR	R	D	D	A	D	R	R
A. lineolata Ehr.	0m														
	1m										RR	D	A		
	3m													RR	R
	7m														
A. marina W. Smith	0m														
	1m		RR					R	M	R	M	D	M	M	M
	3m			RR	R			R	M	M	A	M	A		
	7m					RR	A			R	R	RR	R	R	R
A. ocellata Donkin	0m														
	1m														
	3m														
	7m												RR		R

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
A. ovalis (Kütz.) Kütz.	0m														
	1m								RR	RR	R	RR	R		
	3m														
	7m														
A. pellucida Kütz.	0m									RR	R				
	1m														
	3m														
	7m														
A. sp.	0m								RR	RR	R	R	R	RR	R
	1m								R	RR	R	RR	R		
	3m			R	R	M	A	M	R	R	R	RR	R		R
	7m														
Anaulus balticus Simonsen	0m														
	1m														
	3m									RR	R		R		
	7m														
Auricula minuta Cleve	0m														
	1m														
	3m				RR		R								
	7m														
Bacillaria paxillifer (O.F. Müller) Hendey	0m				RR										RR
	1m														
	3m		R	RR	RR		RR								
	7m		R		RR										
Berkeleya micans (Lyngb.) Grun.	0m					A		A					R		
	1m			A	A	D	D	D	A	R	D	R	R	RR	
	3m		R	D	D	D	D	D	D	R	D				
	7m		A	D	R	D	D	D	D	A	RR				
B. fragilis Grev.	0m										R		R		
	1m			D	D	D	D	D	A	R	D				
	3m		R	D	D	D	D	A	A	R	D				
	7m		M	D	CD	D	D	M	A	R	A				
B. rutilans (Trent.) Grun.	0m			M	A	A		M					M		R
	1m			M	A	M	D	M	A	M	A	A	A	D	M
	3m		RR	M	M	A	A	M	A	M	A	A	A		
	7m		A	CD	D	D	D	A	A	R	D	A	R	A	A
B. scopulorum (Bréb.) Cox	0m														
	1m				M	M	A	A	A	RR	R			RR	
	3m					A	A	R	R	RR	RR				
	7m					M	M	R	R	R	R			RR	
Campylodiscus fastuosus Ehr.	0m														
	1m										R	RR	RR	RR	R
	3m													RR	R
	7m														
Caloneis linearis (Grun.) Boyer	0m				RR		RR								
	1m						RR								
	3m								RR						
	7m														
C. liber (W. Smith) Cleve	0m														
	1m														
	3m										RR		RR		
	7m														
C. fusioides Grun.) Heiden & Kolbe	0m						RR		RR						
	1m														
	3m														
	7m														
C. westii (W. Smith) Hendey	0m														
	1m										RR		RR		
	3m														
	7m														
Climaconeis inflexa (Bréb. ex Kütz.) Cox	0m														
	1m							A	R						
	3m					R	A	A	A						
	7m					R	A	A	A	R	R				
Cocconeis costata Greg.	0m		RR										RR		RR
	1m														
	3m														
	7m														
C. diminuta Pantocsek	0m														
	1m														
	3m														
	7m								RR		R	RR	R		
C. distans Greg.	0m														
	1m		RR		RR		R								
	3m														
	7m														

Table 4. Cont'd

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
C. disculus (Schumann) Cleve	0m														
	1m								R		R			RR	R
	3m														
	7m														
C. molesta Kütz.	0m														
	1m									RR	R				
	3m														
	7m						A	R	R						
C. molesta var. *crucifera* Grun.	0m														
	1m									A	D			RR	R
	3m								R	R	RR	R	R		
	7m						RR	RR	R	A	A	R	RR		
C. pediculus Ehr.	0m														
	1m														
	3m									RR	R				
	7m														
C. peltoides Hust.	0m														
	1m														
	3m														
	7m				RR		RR								
C. placentula Ehr.	0m														
	1m				R		R		RR	RR	R	RR	R		
	3m										R				
	7m														
C. placentula var. *euglypta* (Ehr.) Grun.	0m														
	1m									RR					
	3m									RR					
	7m									RR	R			RR	RR
C. scutellum Ehr.	0m		RR		M		M				D		R		R
	1m			R	R		R	A	A	D	D	R	D	R	A
	3m			R	R	R	R	R	A	R	A	R	RR		
	7m		RR	R	RR	A	M	A	A	R	A	R	A	R	A
C. scutellum var. *parva* (Grun.) Cleve	0m				RR		R		R		R		RR		A
	1m						R	R	R	R	R		R	RR	R
	3m						R					R	R		
	7m				RR		RR				R	R	R		R
C. scutellum var. *speciosa* (Greg.) Cleve	0m														
	1m							RR		RR					
	3m														
	7m									RR			R		
C. stauroneiformis (W. Smith) Okuno	0m														
	1m				RR		R		R	RR	R			RR	
	3m									RR	R				
	7m										RR			RR	R
Coscinodiscus sp.	0m														
	1m														
	3m														
	7m		RR									RR	R	RR	R
Cyclotella sp.	0m								R						
	1m							RR	R	RR					
	3m							R	R						
	7m								R	R	RR	R	A	RR	R
Cylindrotheca closterium (Ehr.) Reiman & Lewin	0m										R	R	R	R	
	1m		RR		R		RR	M	R	D	A	D	M	D	M
	3m		RR	RR	R	R	M	M	M	D	A	A	A		
	7m														
Dimerogramma minor (Greg.) Ralfs.	0m														
	1m														
	3m														
	7m		RR		R		RR		RR						
Diploneis litoralis var. *clathrata* (Donkin) Cleve	0m														
	1m														
	3m														
	7m							RR	R	RR	R			RR	
D. oculata (Bréb.) Cleve	0m														
	1m														
	3m														
	7m									RR	R	RR	R		
D. smithi (Bréb.) Cleve	0m														
	1m									RR					
	3m												RR		
	7m				RR				R	R	R		R		R
D. splendida (Greg.) Cleve	0m														
	1m										RR		R		
	3m									R	R	R	R		
	7m									R	R	R	R		
D. vacillans (Schm.) Cleve	0m														
	1m														
	3m														
	7m		RR		RR		RR								

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
Ditylum brightwellii (West) Grun. var. *tetragona* (Grun.) Hust.	0m														
	1m				RR										
	3m		RR		R		R		RR						
	7m														
Donkinia recta var. *minuta* (Donkin) H. & M. Peragallo	0m														
	1m										RR		R		
	3m														
	7m														
Endyctia oceanica Ehr.	0m				RR		RR								
	1m														
	3m														
	7m														
Entomoneis alata (Ehr.) Ehr.	0m														
	1m														
	3m												RR		R
	7m														
E. gigantea var. *decussata* (Grun.) Poulin & Borard-Therria	0m														
	1m														
	3m								RR		RR		R		
	7m														
E. paludosa (W. Smith) Reimer	0m														
	1m			RR	R			RR	R	RR	R		R	M	R
	3m							R	R	RR	R	R	R		
	7m									RR	R	R	R	R	R
E. paludosa var. *duplex* (Donkin) Czarnecki et Blinn.	0m														
	1m						RR	RR	R	R	A	R	R	RR	
	3m					R	RR	M	M	R	A				
	7m							R	R	R	A	A	A	R	RR
Fallacia forcipata (Grev.) Stickle & Mann	0m														
	1m														
	3m														
	7m		RR		RR		R								
Fragilaria sp.	0m														
	1m								R						
	3m								R						
	7m						R	R	R		M	RR	R	R	R
Grammatophora angulosa Ehr. var. *islandica* (Ehr.) Grun.	0m											R	A	M	A
	1m														
	3m														
	7m														
G. hamulifera Kütz.	0m														
	1m				R		R		RR						
	3m														
	7m														
G. marina (Lyngb.) Kütz. var. *adriatica* Grun.	0m														
	1m														
	3m		R		R		R		RR						
	7m														
G. oceanica Ehr.	0m														
	1m														
	3m				RR		RR								
	7m							R	R	RR	R				
Gyrosigma tenuissimum (W. Smith) Griff. & Henfr.	0m														
	1m									RR	R	RR	R	RR	R
	3m									RR	R	RR	R		
	7m											RR	R	RR	R
G. tenuissimum var. *hyperborea* (Grun.) Cleve	0m											R	R		R
	1m							RR	R	RR	R	R	R		
	3m										R	RR	RR	RR	R
	7m														
Haslea ostrearia (Gaillon) Simonsen	0m														
	1m									R	A				
	3m									RR	A	RR	M		
	7m														
Hemiaulus hauckii Grun.	0m														
	1m														
	3m														
	7m										R	RR	RR		R
Hyalosira delicatula Kütz.	0m		D		D		M								
	1m				A		A								
	3m				M		D								
	7m		R		R		D								
Licmophora abbreviata C. Ag.	0m		R		D		M								
	1m		R	CD	CD	R	R								
	3m		R		M	RR	R	R	RR	R	RR				
	7m		RR		R	R	R	RR	M	RR	RR	RR	R	RR	R

Table 4. Cont'd

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
L. communis (Heiberg) Grun.	0m														
	1m											R		RR	
	3m									R		R	RR	R	
	7m														
L. debilis (Kütz.) Grun.	0m										RR				
	1m										RR				
	3m									RR	A				
	7m									R	R				
L. ehrenbergii (Kütz.) Grun. var. *adriatica*	0m														
	1m			A	R									R	R
	3m		R	R	R	R	R								
	7m					R	R							R	R
L. gracilis (Ehr.) Grun.	0m										R				
	1m										R				
	3m							R			R		RR		
	7m				RR			R			R				
L. gracilis var. *anglica* (Kütz.) H. & M. Peragallo	0m														
	1m										RR				
	3m		R				RR		RR		R				
	7m						R		R		R	RR	RR		
L. grandis (Kütz.) Grun.	0m														
	1m										R		R		
	3m														
	7m									RR	R		R		
L. hyalina (Kütz.) Grun.	0m														
	1m						R		R						
	3m				R		R								
	7m														
L.mediterranea Mereschkowsky var. *adriatica* Mereschkowsky	0m														
	1m		RR		RR		R	RR	R						
	3m														
	7m														
L. paradoxa (Lyngb.) C. Ag. var. *tincta* (C. Ag.) Hust.	0m		R		M										
	1m				D		M		R	RR	R	RR	R	RR	
	3m				D		M			RR	R	RR	R		
	7m				D	R	D		R	RR	R	R	R	RR	R
L. proboscoides Mereschkowsky	0m														
	1m						RR		RR						
	3m														
	7m														
L. reichardtii Grun.	0m				RR		RR								
	1m														
	3m														
	7m														
Leptocylindrus danicus Cleve	0m														
	1m									RR	M	RR	R		
	3m														
	7m														
Mastogloia apiculata W. Smith	0m														
	1m														
	3m														
	7m											RR	R	RR	R
M. smithi Thwaites var. *amphicephala* Grun.	0m														
	1m												RR		R
	3m														
	7m														
M. quinquecostata var. *hartzschii* Grun. ex Cleve et Müll.	0m														
	1m														
	3m														
	7m												RR		R
Melosira moniliformis (O.F. Müll) C. Ag.	0m														
	1m														
	3m					RR	R	R	R						
	7m									RR	R				
Navicula sp.	0m								R						
	1m							A	M	R	R	D	A	A	A
	3m							R	M	RR	R	A	A		A
	7m		R	RR	R	RR	R	R	R	RR	R	A	D	A	M
N. complanata (Grun.) Grun.	0m														
	1m											R	A		
	3m											RR	RR		
	7m														
N. consentanea Hust.	0m		R		R										
	1m						R		R						
	3m		RR												
	7m		R		R		RR			RR					
N. cryptocephala Kütz.	0m														
	1m														
	3m		RR		R		RR								
	7m							RR	R	RR					

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
N. cryptocephala Kütz. var. *veneta* (Kütz.) Rabenh.	0m														
	1m														
	3m		RR		RR		RR								
	7m														
N. directa (W. Smith) Ralfs.	0m														
	1m														
	3m														
	7m		R		R								RR		
N. fromenterae Cleve	0m														
	1m						RR		RR						
	3m														
	7m														
N. gibbula Cleve	0m				R		R		RR						
	1m														
	3m														
	7m														
N. inflexa (Greg.) Ralfs. in Pritch.	0m														
	1m										CD		M		
	3m														
	7m														
Navicula palpebralis Bréb. ex W. Smith	0m														
	1m														
	3m														
	7m						R		RR						
N. ramosissima (C. Ag.) Cleve)	0m		R		RR		R				A		M		A
	1m				R	RR	R	A	M	D	A	R	R	A	A
	3m		RR	M	R	R	R	R	R	D	A	M	A	A	A
	7m		RR	R	R	R	R	A	A	D	D	A	M	D	A
N. ramosissima var. *torquata* (Harvey) R. Ross	0m				RR		RR		R		R		A		A
	1m				R	RR	R	D	D	M	A	R	A	R	A
	3m				R	R	R	RR	R	R	M	D	D		
	7m		RR	RR	RR	R	RR	D	R	D	D	D	D	A	R
N. salinicola Hust.	0m		RR		RR										
	1m				R										
	3m			R	RR										
	7m		RR	R	RR	RR	RR	R	RR						
Nitzschia dissipata (Kütz.) Grun.	0m														
	1m														
	3m												A		M
	7m												RR		RR
N. distantoides Hust.	0m				R										
	1m					RR	R								
	3m														
	7m														
N. distans Greg.	0m														
	1m					RR	RR	RR	R						
	3m														
	7m														
N. reversa W. Smith	0m														
	1m		RR	RR	R			R	R	M	A	R	M	RR	R
	3m							R	R	M	A	R	R		
	7m					RR	RR	RR	R	R	M	RR	R	RR	R
N. lorenziana Grun.	0m														
	1m												R		
	3m														
	7m				R		R		R		RR				
N. pseudohybrida Hust.	0m														
	1m														
	3m		R				R								
	7m		RR		R		RR		R						
N. sigma (Kütz.) W. Smith	0m				S		RR								
	1m														
	3m						RR		R	RR	R	RR	R		
	7m						R		RR		RR		RR		
N. socialis Greg.	0m														
	1m										A				
	3m										R				
	7m										R				
N. sp. 1 (111)*	0m														
	1m							A	A	D	D	D	M	R	A
	3m							A	R	D		A	A		
	7m						RR	R	R	R	R	D	A	M	M
N. sp. 2 (112)*	0m						D		D		D		D		D
	1m							A	D	R	R	R	R	A	M
	3m							M	R	D	M	D	M		
	7m						R	R	RR	R	RR	D	R	A	R
N. sp. 3 (113)*	0m														
	1m							A	M	A	R	R	R	R	R
	3m							R	RR	A	R	A	R		
	7m							A	R	R		R	R	D	R

Table 4. Cont'd

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
N. valdestriata Allem & Hust.	0m		RR		R										
	1m				RR	R	RR								
	3m														
	7m														
Opephora olsenii Möller	0m														
	1m														
	3m														
	7m							R	R						
Paralia sulcata (Ehr.) Cleve	0m														
	1m														
	3m														
	7m		R		R		RR								
Pinnularia sp.	0m														
	1m														
	3m		RR		R		R								
	7m				RR		RR		RR						
Pleurosigma elongatum W. Smith	0m														
	1m								R	R	R	R	R	RR	R
	3m										R	RR	R		
	7m														
Podosira stelligera (Bail.) Mann	0m				RR		R								
	1m														
	3m														
	7m														
Psammodictyon panduriforme (Greg.) D.G. Mann	0m				RR		R				R		A		RR
	1m				RR		M	R	RR	A	A	A	D	RR	R
	3m				RR		RR	R	R	R	A	R	M		
	7m		R		RR		R	R	R	M	D	R	A	RR	R
Rhopalodia operculata (C. Ag.) Hakonson	0m														
	1m														
	3m											R	R	R	M
	7m											RR	R	RR	R
Rhaphoneis amphiceros (Ehr.) Ehr. var. *rhombica* Grun.	0m											RR	RR	RR	RR
	1m														
	3m														
	7m														
Stauroneis decipiens Hust.	0m														RR
	1m									R	R				
	3m							RR	R	RR	RR	R	R	RR	R
	7m														R
S. sp.	0m														
	1m														
	3m							RR	RR		R		R	RR	RR
	7m														
Staurosira construens var. *binodis* (Ehr.) Hamilton	0m														
	1m														
	3m														
	7m					R	R		R		R				
Staurosirella pinnata (Ehr.) Williams & Round	0m														
	1m														
	3m														
	7m					R	R	R	R						
Striatella unipunctata (Lyngb.) C. Ag.	0m				RR		R		R		R		M		M
	1m		R	D	M	M	M	RR	A	A	A	R	R	R	R
	3m		A	A	M	M	M	R	A	M	A	RR	R		
	7m		R	R	R	R	R	RR	R	R	A	RR	R	R	R
Synedra berolinensis Lemm.	0m														
	1m														
	3m		RR		RR		RR								
	7m														
S. closterioides Grun.	0m											RR	R		
	1m														
	3m		RR									RR	R		R
	7m		R												
S. ehrenbergi Kütz.	0m														
	1m		RR		RR		R								
	3m														
	7m														
S. fulgens (Grev.) W. Smith	0m														
	1m								RR	R	R	RR	R		
	3m									RR	RR	RR	R		
	7m						R		R		R		RR		
S. gaillonii (Bory) Ehr.	0m				CD		A		A		R				
	1m										RR				
	3m									R	RR				
	7m						RR		R		R				
S. gaillonii (Bory) Ehr.var. *minor* Kütz.	0m														
	1m														
	3m														
	7m								RR						

		March		April		May		June		July		August		October	
	depth	M	P	M	P	M	P	M	P	M	P	M	P	M	P
S. hennedyana Greg.	0m														
	1m														
	3m										R		R		
	7m														
S. laevigata Grun. in Hust.	0m				M		R						A		A
	1m				M		R	RR	R	R	R	R	R	RR	R
	3m		D		M		R		M	R	R	R	A	R	M
	7m		D		M		R		R				R		
S. laevigata var. *hyalina* Grun.	0m				M										
	1m				D										
	3m		A		D		M		R						
	7m		M		RR										
S. toxoneides Castracane in Hust.	0m														
	1m							R	M	R	M				
	3m									M	A				
	7m														
S. undulata (Bail) W. Smith	0m		RR		RR		R								
	1m							RR	RR	R	A	R	M		
	3m		RR	RR	R	R	R	R	R	R	A	R	R		
	7m			RR	R	R	M	R	RR	RR	A	RR	R		RR
Tabellaria fenestrata (Lyngb.) Kütz.	0m														
	1m														
	3m														
	7m						RR		RR		R				
Tabularia fasciculata (C. Ag.) Williams & Round	0m								R						
	1m							RR	A	R	A	RR	M	RR	R
	3m									R	R				
	7m									R	R	R	RR		
T. investiens (W. Smith) Williams & Round	0m		R		R		RR		R		R				
	1m		M		M	RR	R	RR	R	R	A	R	RR		
	3m		R		M		RR	R	R	A	R	R	M		
	7m		R		R		R		R		M				
T. tabulata (C. Ag.) Snoeijs	0m		D		M		M				R		A		
	1m		R		R	RR	R	RR	RR	RR	RR	R	A	RR	M
	3m		R	R	R	RR	RR	RR	A	R	M				
	7m		RR		R	R	R	RR	R	R	R			R	
T. tabulata var. *parva* (Kütz.) Hust.	0m						R		R		A		R		
	1m		R							RR	A			RR	R
	3m		R	R	R					RR	M				
	7m							RR			A		R		M
Thalassionema nitzschioides Grun.	0m														
	1m				R								R		
	3m		RR	R	RR		R								
	7m				RR		R								
Thalassiophysa hyalina (Grev.) Paddock & Sims	0m														
	1m									RR					
	3m									RR					
	7m														
Thalassiosira rotula Méun.	0m														
	1m														
	3m														
	7m										R		RR		RR
Thalassiothrix frauenfeldii (Grun.) Grun.	0m														
	1m														
	3m														
	7m										R		R		RR
Trachyneis aspera (Ehr.) Cleve	0m				RR										
	1m				RR		RR		R	RR	RR				
	3m		RR		R		R			RR	R				
	7m													RR	R
T. aspera var. *elliptica* Hendey	0m				RR		RR		R						
	1m														
	3m														
	7m														
Trachysphaenia australis Petit	0m														
	1m														
	3m														
	7m											R	RR	R	R
Tryblionella apiculata Greg.	0m														
	1m														
	3m				RR	R	RR		RR						
	7m														
T. debilis A. Mayer	0m												RR		
	1m										R		RR		
	3m										M		R		
	7m														

Legend:
M – monthly plate, P – permanent plate
D – dominant, CD - codominant, A – abundant, M – common, R – rare, RR – very rare, S – single specimens

* undetermined species treated by P. Hamilton