

# ANNALES

*Anali za istrske in mediteranske študije*  
*Annali di Studi istriani e mediterraneei*  
*Annals for Istran and Mediterranean Studies*  
17/99







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## VSEBINA / INDICE GENERALE / CONTENTS

BIOLOGIJA IN EKOLOGIJA MORJA  
BIOLOGIA ED ECOLOGIA MARINA  
MARINE BIOLOGY AND ECOLOGY

**Ulrich Fiedler & Ehud Spanier:** Occurrence of larvae of *Scyllarus arctus* (Crustacea, Decapoda, Scyllaridae) in the eastern Mediterranean - preliminary results ..... 153  
*Pojavljanje larv raka Scyllarus arctus (Crustacea, Decapoda, Scyllaridae) v vzhodnem Sredozemlju - predhodni rezultati*

**Tom Turk:** Poisonous and venomous animals in the Northern Adriatic ..... 159  
*Strupeni organizmi severnega Jadrana*

**Ennio Vio & Raffaella De Min:** I molluschi del litorale marino di Cervera (Parenzo, Istria) ..... 167  
*Mehkužci morskega obrežja pri Črvarju (Poreč, Istra)*

**Patricija Mozetič, Vlado Malačič & Valentina Turk:** Ecological characteristics of seawater influenced by sewage outfall ..... 177  
*Ekološke značilnosti obalnega morja v bližini podvodnega kanalizacijskega izpusta*

**Elisabetta Sdrigotti, Vittorio Barbariol & Chiara Welker:** Diatom assemblages in coastal shallow water at the water sediment interface (Gulf of Trieste, North Adriatic Sea) ..... 191  
*Kopičenje diatomej na vmesni plasti vodnih usedlin v obalnih vodah Tržaškega zaliva (severni Jadran)*

**Borut Vrišer & Aleksander Vukovič:** Seasonal and long-term variability of meiofauna in the environment frequently affected by hypoxia in central part of the Gulf of Trieste ..... 203  
*Sezonske in večletne spremembe meiofavne v okolju pogosto prizadetim s hipoksijami v osrednjem delu Tržaškega zaliva*

**Borut Vrišer:** Meiofavna Strunjanskega zaliva 18 let pozneje: ponovljena raziskava ..... 209  
*Meiofauna in the bay of Strunjan 18 years after: A repeated investigation*

**Matej David:** Vnos tujerodnih organizmov v severnem jadrano in upravljanje balastnih vod ..... 213  
*Introduction of nonindigenous organisms in the Northern Adriatic and ballast water management*

IHTIOLOGIJA  
ITTILOGIA  
ICHTHYOLOGY

**Jakov Dulčić:** Early life history stages of family Centrolophidae in the eastern Adriatic ..... 223  
*Zgodnji razvojni stadij rib iz družine Centrolophidae v vzhodnem Jadrano*

**Alen Soldo, Melita Peharda, Vlado Onofri, Nikša Glavić & Pero Tutman:** New record and some morphological data of the Basking Shark *Cetorhinus maximus* (GÜNNERUS, 1765), in the eastern Adriatic ..... 229  
*Nov zapis in nekaj morfoloških podatkov o morskem psu orjaku Cetorhinus maximus (GÜNNERUS, 1765) iz vzhodnega Jadrana*

**Jakov Dulčić:** Age and growth studies on fishes in Croatian fisheries science ..... 233  
*Študije o starosti in rasti rib v hrvaški ihtiološki znanosti*

GEOLOGIJA IN PALEONTOLOGIJA  
GEOLOGIA E PALEONTOLOGIA  
GEOLOGY AND PALEONTOLOGY

**Davide Lenaz:** <sup>87</sup>Sr/<sup>86</sup>Sr isotopic characterisation of dolina soils and flysch from Trieste area (NE Italy) ..... 239  
*<sup>87</sup>Sr/<sup>86</sup>Sr izotopska karakterizacija prsti dolin in fliših plasti iz okolice Trsta (SV Italija)*



|   |  |
|---|--|
| <b>Inna A. Dobruskina, Bogdan Jurkovšek &amp; Tea Kolar-Jurkovšek:</b> Upper Cretaceous flora of Slovenia ..... 243<br><i>Zgornjekredna flora Slovenije</i>   | <b>DELO NAŠIH ZAVODOV IN DRUŠTEV</b><br><b>ATTIVITÀ DEI NOSTRI ISTITUTI E DELLE NOSTRE SOCIETÀ</b><br><b>ACTIVITIES BY OUR INSTITUTIONS AND ASSOCIATIONS</b>   |
| <b>Rajko Pavlovec &amp; Ingrid Simčič:</b> Numulitine iz okolice Vipolž v Goriških brdih ..... 269<br><i>The nummulitins from the surrounding of Vipolže in Goriška brda (western Slovenia)</i>   | <b>Alenka Malej &amp; Mitja Bricelj:</b> Sredozemski akcijski načrt (MAP) in program MED POL v Sloveniji ..... 331<br><i>Mediterranean action programme (MAP) and MED POL programme in Slovenia</i>  |
| <b>Mauro Caffau &amp; Ioanna Protopsalti:</b> A study of the morphological variability of <i>Radiolites marinii</i> Caffau & Pleničar (Radiolitidae), Late Cenomanian, Karst of Gorizia, Italy ..... 281<br><i>Študija o morfološki variabilnosti Radiolites marinii Caffau &amp; Pleničar (Radiolitidae), višji cenomanij, goriški Kras, Italija</i> | <b>Boris Petelin:</b> Workshop on Benefits of the Implementation of the Global Ocean Observing System in the Mediterranean Region, Rabat - Morocco, 1-3 November 1999 ..... 334<br><i>Delavnica o koristih uresničevanja globalnega sistema opazovanja morij v Sredozemju, Rabat - Maroko, 1.-3. novembra 1999</i> |
| FAVNA<br>FAUNA<br>FAUNA   | <b>Sonja Škornik:</b> Poročilo o simpoziju "Flora in vegetacija Slovenije 1999" Gozdarski inštitut Slovenije, Ljubljana, 26.-27. 11. 1999 ..... 336<br><i>A report on the Symposium "Flora and Vegetation of Slovenia 1999"</i>  |
| <b>Iztok Geister:</b> Gnezdilke popogoriščnega habitata na Petrinjskem Krasu ..... 299<br><i>Breeding birds of a post-conflagrated habitat in the Petrinje Karst</i>  | <b>Vesna Flander Putrle:</b> Advanced study course on the Mediterranean Marine System (4-17 July 1999 in Barcelona, Spain) ..... 336<br><i>Nadaljevalni tečaj o sredozemskem morskem sistemu (4.-17. julij 1999, Barcelona, Španija)</i>   |
| <b>Boštjan Surina:</b> Ptice zgornjega dela doline Reke in bližnje okolice ..... 303<br><i>Ornithofauna of the upper Reka valley and its neighbourhood</i>  | <b>OCENE IN POROČILA</b><br><b>RECENSIONI E RELAZIONI</b><br><b>REVIEWS AND REPORTS</b>  |
| <b>Boris Kryštufek &amp; Andrej Hudoklin:</b> Netopirji na prezimovališčih v Sloveniji v letih 1994-1996 ..... 315<br><i>Bats in hibernaculas of Slovenia 1994-1996</i>   | <b>James Higginbotham:</b> Piscinae. Artificial fishponds in Roman Italy ( <b>Matej Župancič</b> ) ..... 338   |
| <b>Andrej Hudoklin:</b> Letna dinamika pojavljanja podkovnjakov ( <i>Rhinolophus</i> spp.) v nekaterih jamah na Dolenjskem ..... 323<br><i>Annual dynamics of the occurrence of horseshoe bats (Rhinolophus spp.) in some caves of Dolenjska</i>  | <b>Thomas C. Malone, Alenka Malej, Lawrence W. Harding, Jr., Nenad Smoljaka &amp; R. Eugene Turner (Eds.):</b> Ecosystems at the Land-Sea Margin - Drainage Basin to Coastal Sea, American Geophysical Union, Washington ( <b>Lovrenc Lipej</b> ) ..... 340  |
|   | Navodila avtorjem ..... 342<br><i>Instructions to authors</i> ..... 344  |
|   | Kazalo k slikam na ovitku ..... 346<br><i>Index to pictures on the cover</i>   |

## SUPLEMENT

SREDOZEMSKO KMETIJSTVO IN OLJKARSTVO  
AGRICOLTURA E OLIVICOLTURA MEDITERRANEA  
MEDITERRANEAN AGRICULTURE AND OLIVE  
GROWING**Jorge E. Spangenberg & Nives Ogrinc:**

Characterization of olive oils from Slovenia  
and Croatia by compound specific  
isotope analysis ..... 1  
*Uporaba stabilnih izotopov ogljika pri  
karakterizaciji oljčnega olja iz Slovenije  
in Hrvaške*

**Tom Levanič:** Težave pri ugotavljanju dejanske  
starosti oljk (*Olea europaea* L.) v Slovenski Istri ..... 5  
*Difficulties in the assessment of the actual  
age of olive trees (Olea europaea L.)  
in Slovene Istra*

**Anamarija Plestenjak & Terezija Golob:**  
Vrednotenje senzoričnih lastnosti oljčnih olj ..... 11  
*Evaluation of the sensory characteristics  
of olive oils*

**Bojan Butinar, Milena Bučar Miklavčič  
& Darinka Čalija:** Polifenoli v oljčnih oljih  
Slovenske Istre letnika 94 ..... 17  
*Polyphenols in olive oils from  
Slovene Istra crop 94*

**Bojan Butinar, Milena Bučar Miklavčič  
& Darinka Čalija:** Skupni polifenoli, hidroksitirol  
in tirosol v oljčnih oljih Slovenske Istre v dveh  
zaporednih letih (1996, 1997) ..... 27  
*Total polyphenols, hydroxytyrosol and tyrosol  
in the olive oils of Slovene Istra in two  
consecutive years (1996, 1997)*

**Bojan Butinar, Milena Bučar Miklavčič  
& Darinka Čalija:** Tokoferoli v oljčnih oljih  
Slovenske Istre v treh zaporednih letih ..... 37  
*Tocopherols in olive oils from Slovene Istra  
in three consecutive years*

**Boštjan Godec, Boris Koruza, Barbara Ambrožič-  
Turk & Viljanka Vesel:** Postopek pridobivanja  
certificiranega sadilnega materiala  
oljke (*Olea europaea* L.) ..... 47  
*Procedure for the acquisition of certified oliva  
(Olea europaea L.) planting material*

**Viljanka Vesel:** Vpliv tretiranja in različnih  
obdobij priprave potaknjencev na ukoreninjanje  
dveh kultivarjev oljk (*Olea europaea*) ..... 53  
*Influence of treatment and different preparation  
period of cuttings on rooting of two olive  
varieties (Olea europaea)*



**BIOLOGIJA IN EKOLOGIJA MORJA**  
**BIOLOGIA ED ECOLOGIA MARINA**  
**MARINE BIOLOGY AND ECOLOGY**





## OCCURRENCE OF LARVAE OF *SCYLLARUS ARCTUS* (CRUSTACEA, DECAPODA, SCYLLARIDAE) IN THE EASTERN MEDITERRANEAN - PRELIMINARY RESULTS

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### ABSTRACT

*Phyllosoma* larvae of the broad lobster *Scyllarus arctus* (Crustacea: Decapoda: Scyllaridae) were sampled by plankton nets in the Eastern Mediterranean. A scheme for distinguishing between larval stages is suggested. It describes the characteristic features of phyllosoma stages 3 to 12. Phyllosomes of the studied species were found almost all year round and nearly all stages were represented in the samples. Findings of early stage larvae may indicate a spawning season mainly from February to April and from July to September. Most larvae were caught at considerable distances offshore. Larvae were sampled mostly in four long-term persistent or recurrent eddies. Data from physical studies imply an increased probability that phyllosomes can be trapped in eddies for a relatively long period of time while drifting away from the coast. The possible ecological significance of this finding is discussed.

**Key words:** Zooplankton, *Phyllosoma* larvae, Crustacea, Decapoda, Scyllaridae, *Scyllarus*

### INTRODUCTION

In comparison with the wealth of information available on the biology and ecology of larval stages of clawed lobsters, Nephropidae (e.g., Cobb and Wahle, 1994; Factor, 1995) and of spiny lobsters, Palinuridae (e.g., Kittaka, 1994), the knowledge of the larval stages of slipper lobsters, Scyllaridae, is scanty, especially on the Mediterranean species. In the Eastern Mediterranean this family is represented by two genera, *Scyllarides* and *Scyllarus* (Holthuis, 1991). Only one species of the first genus, *S. latus*, (Latreille, 1803), and two of the latter, *S. arctus* (Linnè, 1758) and *S. pygmaeus* (Bate, 1888), are reported from this area (Seridji, 1989). The complete larval development of none of these species is known. Within the genus *Scyllarus*, phyllosoma larvae spend up to four months drifting in the ocean (Phillips & McWilliam, 1989). How is larval dispersal controlled in the open sea in view of various physical "obstacles" such as

eddies, or do they use these circling currents as a "development-loop" until metamorphosis?

In the Eastern Mediterranean, mesoscale eddies are recognized as potentially important oceanographic features (Robinson *et al.*, 1987, 1991). In this area, four long-term persistent or recurrent eddies have been investigated: a cyclonic, cold-core eddy south of Crete, two anti-cyclonic eddies at the Herodotus basin (Mersa Matruh and one eddy just north of it) and the anti-cyclonic Shikmona eddy south of Cyprus (Brenner, 1993). The diameter of the last eddy is approximately 150 km. Krom *et al.* (1991) found the waters in the core of the Shikmona eddy near Cyprus to be sealed off the surrounding waters. This is apparently true also for the Mersa Matruh and the eddy off Crete (Hecht, *personal communications*).

Stephensen (1923) found numerous phyllosoma larvae of the broad lobster *S. arctus* in plankton samples of the Thor expedition (1908-1910) in the Mediterranean.

He was able to distinguish the different larval stages starting with phyllosoma stage I that had been previously described by Dohrn (1870) based on larvae hatched from eggs of *S. arctus* in the laboratory.

The identification of larvae for the present study was based on Stephensen (1923). Our findings suggest several additions and corrections of his staging system, which are briefly stated in the identification scheme below.

Larvae of only two species of *Scyllarus* have been successfully reared in the laboratory (Robertson, 1968: *Scyllarus americanus*; Ito & Lucas, 1990: *Scyllarus demani*). Their descriptions of larval stages were used to confirm our staging system. As long as there are not enough results from laboratory rearing experiments, a key based on defining stages from field material may be a useful tool, despite its limitations. Thus, identification of larvae enables the attempt done in the present study relating their spatial and temporal distribution to their physical environment.

#### MATERIALS AND METHODS

The larvae used in this study were collected during cruises conducted by the Israel Oceanographic and

Limnological Research (IOLR), Haifa, as part of the international POEM (Physical Oceanography of the Eastern Mediterranean) Program and the IOLR-Eddy-Program. From the summer of 1988 until the spring of 1990 several cruises were made with the R/V Shikmona II in the Eastern Mediterranean. A total of (50) stations, located in two arrays, were sampled in the Eastern Mediterranean. The locations of the sampling stations are given in Figure 1.

During these cruises, oblique plankton hauls were taken using a General Oceanics plankton net (60 cm in diameter, 500  $\mu\text{m}$  mesh size) and a mesopelagic net (1 m<sup>2</sup> squared mouth, 1000  $\mu\text{m}$  mesh size), both equipped with a 25 kg depressor and a General Oceanics digital flow meter. A neuston net (50 x 20 cm half submerged mouth, 500  $\mu\text{m}$  mesh size) was also used. During the POEM-cruises 1988 - summer 1989 only the General Oceanics net was employed and from fall 1989 - spring 1990 only the mesopelagic net was used. The General Oceanics net and the neuston net were used alternating during the IOLR-eddy-program cruises. Samples were taken randomly at all times. Approximately 400 m<sup>3</sup> of seawater were filtered per haul (General Oceanics and mesopelagic net). The neuston net was towed for 15 minutes with a speed 2 kn, resulting 0.5 nm towing range.

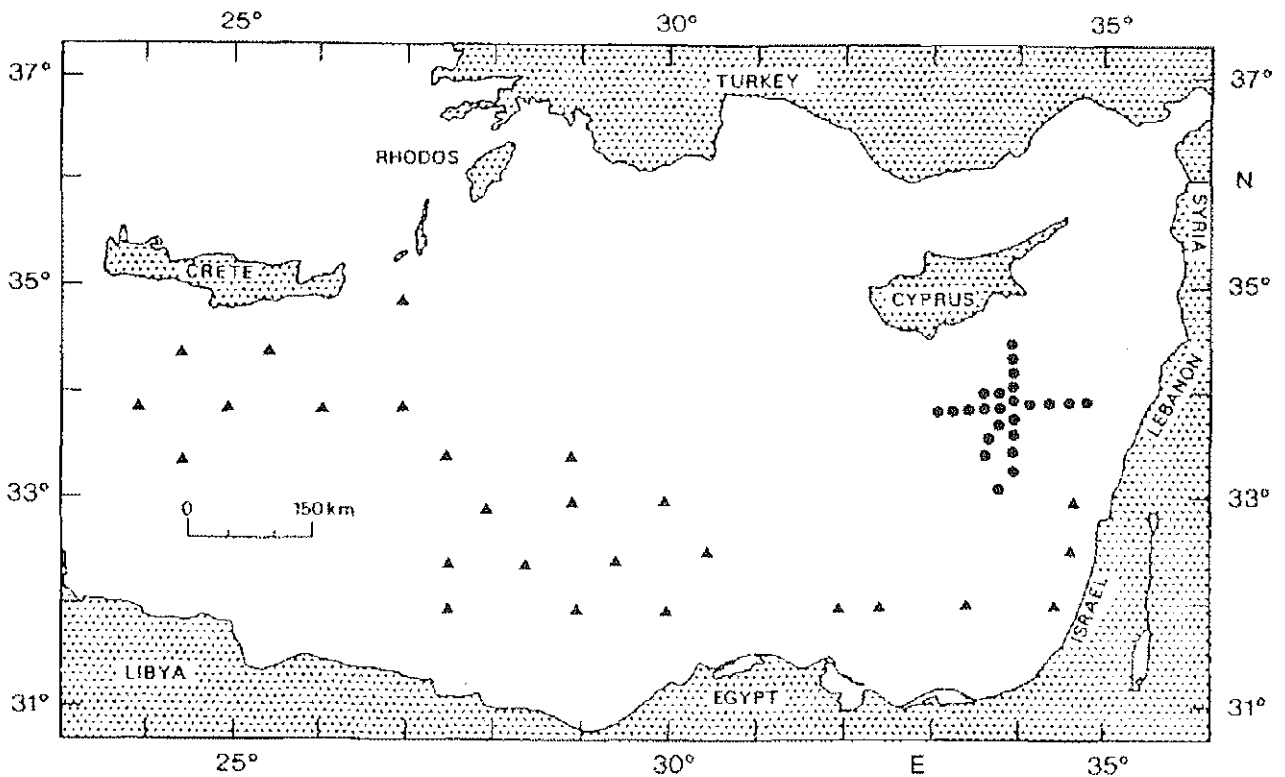


Fig. 1: Sampling stations of the present study. Dots: POEM cruises, triangles: IOLR eddy cruises.

Sl. 1: Vzorčevalne postaje. Pike: križarjenja v organizaciji POEM (Physical Oceanography of the Eastern Mediterranean). Trikotniki: križarjenja v organizaciji IOLR (Israel Oceanography and Limnological Research) za preučevanje morskih vrtincev.



Tab. 1: Identification scheme for phyllosoma stages of *Scyllarus arctus*.

Tab. 1: Identifikacijska shema stadijev filosom raka *Scyllarus arctus*.

List of abbreviations: Abd-Abdomen; biram biramous; Cs-Cephalic shield; L-length; Mx-Maxilla; Mxp-Maxilliped; Per-Pereiopod (Per 1-4: numbers of natatory setae on the exopodite); Pleop-Pleopod; pres.-present; T-total; Th-Thorax; Urop-Uropods; W-width.

Dimensions are given in mm.

| Stage              | 3       | 4        | 5      | 6       | 7 | 8               | 9         | 10        | 11              | 12                 |
|--------------------|---------|----------|--------|---------|---|-----------------|-----------|-----------|-----------------|--------------------|
| Stephensens system | III     | IV       | V      | V       |   | VI              | VI        | VII       | VIII            | IX                 |
| No exam.           | 2       | 4        | 1      | 3       |   | 5               | 3         | 3         | 1               | 2                  |
| T-L                | 3.3-3.4 | 4.3-4.9  | 6.1    | 7.0-7.9 |   | 10.1-12.3       | 12.8-13.7 | 15.5-17   | 19              | 21.6-24.4          |
| Cs-L               | 2.2-2.3 | 2.9-3.2  | 4.3    | 4.9-5.5 |   | 7.0-8.3         | 8.7-9.2   | 10.2-11.9 | 12.1            | 12.7-14.5          |
| Cs-W               | 2.3-2.5 | 3.2-3.6  | 4.7    | 5.6-6.3 |   | 8.5-10.4        | 10.7-11.2 | 12.3-13.9 | 15.0            | 16.1-18.0          |
| Th-W               | 1.2     | 1.5-1.8  | 2.2    | 2.5-2.7 |   | 3.3-4.1         | 4.5-4.8   | 5.2-5.8   | 6.2             | 6.8-7.6            |
| Cs-W/Th-W          | 2.0-2.1 | 2.1-2.2  | 2.1    | 2.2-2.3 |   | 2.3-2.6         | 2.3-2.5   | 2.3-2.5   | 2.4             | 2.4                |
| Abd-L              | 0.3     | 0.4      | 0.5    | 0.6-0.7 |   | 1.0-1.5         | 1.5-1.9   | 2.0-2.6   | 3.25            | 5.0-5.7            |
| Abd-W              | 0.2-0.3 | 0.3-0.4  | 0.6    | 0.7-0.9 |   | 1.3-1.9         | 2.0-3.0   | 2.9-3.2   | 3.8             | 5.0-5.6            |
| Mxp1               | o       | o        | <Mx2   | <Mx2    |   | =Mx2            | =Mx2      | =Mx2      | =Mx2            | biram              |
| Per1               | 10      | 12-13    | 14     | 15-16   |   | 19-22           | 21-22     | 23        | 24              | 25-27              |
| Per2               | 10      | 12-13    | 14     | 15-16   |   | 20-22           | 22-23     | 23        | 24              | 25-27              |
| Per3               | 6-7     | 8-11     | 11     | 13      |   | 17-19           | 19-22     | 21        | 22              | 24-25              |
| Per4               | 2       | 4-7      | ?      | 9-11    |   | 15-16           | 17        | 19        | 20              | 21-23              |
| Per5-L             | 0.03    | 0.03-0.2 | 0.3    | 0.2-0.3 |   | 0.4-0.7         | 0.6       | 1.2-1.4   | 1.8             | 3.5-4.1            |
| Gills              | o       | o        | o      | o       |   | o               | o         | o         | o               | pres.              |
| Pleop              | o       |          | o      |         |   | pres.           | pres.     | bilobed   | bilobed         | bilobed, elongated |
| Urop               | o       | o        | o      |         |   | bilobed         | bilobed   | bilobed   | bilobed         | bilobed            |
| Abd.               | concav  | concav   | concav |         |   | slightly concav | straight  | straight  | slightly convex | convex             |

Samples were preserved in 4% buffered formaldehyde/seawater. Specimens were examined and measured in natural seawater. The identification of specimens followed Stephensen (1923). In addition his staging system was modified. A brief identification table for the phyllosoma stages of *S. arctus* was developed (Table 1). This scheme uses morphological and morphometrical features; yet, mainly morphological characters were used for the final definition of stages. The most characteristic features are emphasized in the text of Table 1 by bold letters. Due to the relatively small number of specimens, no means or medians are given. This scheme is based only on material of the present study. Some phyllosoma stages are, therefore, not included.

RESULTS AND DISCUSSION

A total of 32 phyllosoma-larvae were found in these samples, 24 of which were identified as *S. arctus* larvae. Two of the remaining phyllosoma are most probably *Scyllarides latus* larvae (stage II), since they resemble closely the known first stage larvae of this species. Six phyllosoma could not be identified until now. A brief scheme for the identification of phyllosoma stages of *S. arctus* is presented in Table 1.

Sizes and morphological features of sampled phyllosoma agree well with Stephensen's (1923) description. We added to his larval description some morphological and morphometrical data. A detailed identification key to the phyllosoma stages of *S. arctus* is in preparation. The main difference between our scheme and Stephensen's is the splitting of his stages V and VI into at least two additional stages respectively. The absence or presence of uropods and the dimensions of cephalic shield and thorax shield are the key features for separating our stages 5 and 6. The gap between our stage 6 and 8 let us hypothesize a 7<sup>th</sup> phyllosoma stage, despite no specimens being sampled. The drastic increase in the number of setae per pereiopod between our stages 6 and 8 and the morphometrical data suggest a presence of an intermediate stage. The 8<sup>th</sup> and 9<sup>th</sup> stages are mainly distinguished by morphometrical differences.

Two *Scyllarus* species have been reared in the laboratory (Robertson, 1968; Ito & Lucas, 1990). Both developed within a few weeks and passed through 7 to 8 phyllosoma stages. There are only slight differences in the total length and development of maxilliped 1 and natatory setae on pereiopods between *S. arctus* and *S. americanus* stages 3-8 (Robertson, 1968). Uropods, pleopods and gills appear earlier in *S. americanus* lar-

vae. *S. demani* (Ito & Lucas, 1990) differs in size from *S. arctus*, but the development of morphological features is similar. *S. americanus* and *S. arctus* develop natatory setae on pereopod 4 in stage 4, while *S. demani* develops such setae in stage 5. Last larval stages of *S. americanus* and *S. demani* are smaller than *S. arctus* stage 12. *S. kitanoviriosus* stage 8 (Wada *et al.*, 1989) and *S. timidus* stage 9 (Ritz, 1977) fall into approximately the same size range we found in *S. arctus*, in agreement to Stephensen's findings. Stephensen's system already consisted of 9 stages, more than described by Robertson and Wada *et al.* (1989). The duration of larval development of *S. americanus* described by Robertson is by far shorter than the duration of larval life suggested by larval findings for other species. Therefore the number of instars may vary, whereas the general developmental features remain constant.

Phyllosoma larvae of *S. arctus* were found in all seasons except winter (Tab. 2). Nearly all phyllosoma stages are represented in the samples. Larval stages in March ranged from stage 4 up to the last larval stage. Younger stages were found in spring, and fall; latest stages in spring and summer. Most larvae were found in March (54.2%) and May (20.8%). Rothlisberg *et al.*

(1994) found significant differences in larval catches of stage I larvae between 142 µm and 500 µm mesh size. Since we did not use any net with less than 500 µm mesh size, the lack of stage I and II larval catches may be explained.

Basing on plankton material from the Mediterranean Sea, Stephensen (1923) suggested that the main spawning season was in summer. Zariquiey Alvarez (1968) found ovigerous females in the Western Mediterranean from February to April and from July to September. Our sampling of phyllosomes within the early stages confirms the results of Zariquiey Alvarez, with the exception of one stage 3 phyllosoma found in November. It may

Tab. 2: Times and stages of sampled phyllosoma larvae. Tab. 2: Meseci in stadiji vzorčenih filusom.

| Month / Stages | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|----------------|---|---|---|---|---|---|---|----|----|----|
| March          |   | 3 | 1 | 1 |   | 2 | 2 | 2  | 1  | 1  |
| May            |   |   |   | 1 |   | 3 | 1 |    |    |    |
| August         |   |   |   |   |   |   |   |    |    | 1  |
| September      | 1 | 1 |   |   |   |   |   | 1  |    |    |
| November       | 1 |   |   | 1 |   |   |   |    |    |    |

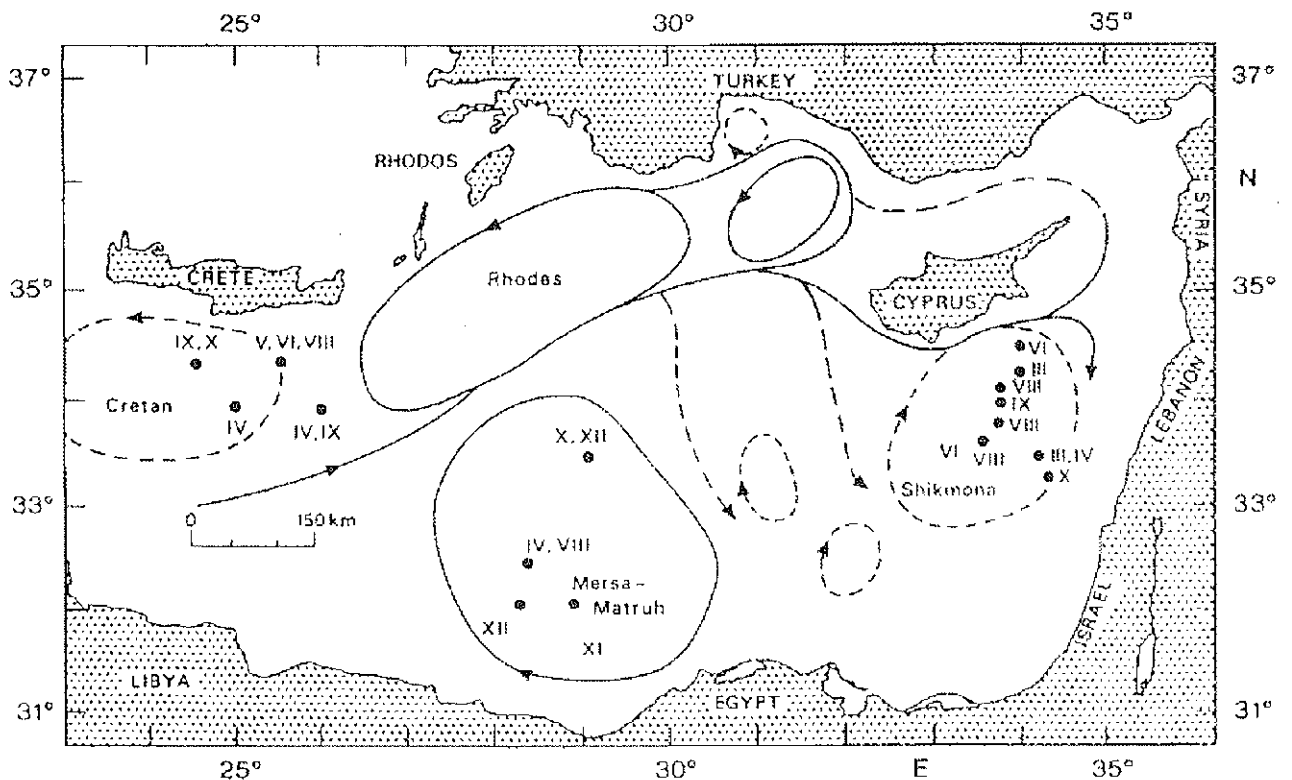


Fig. 2: Sampling locations of phyllosoma larvae of *Scyllarus arctus* of the present study and schematic general circulation of the Eastern Mediterranean (from Robinson *et al.*, 1991). Roman numerals: phyllosomes's stage; names of gyres according to Robinson *et al.* (1991).

Sl. 2: Vzorčevalne lokacije filusom raka *Scyllarus arctus* in shematsko splošno kroženje vzhodnega Sredozemskega morja (po Robinsonu *et al.*, 1991). Rimske številke: stadiji filusom; imena spiral po Robinsonu *et al.* (1991).



indicate a different spawning pattern in the Eastern Mediterranean. Similarly, Spanier *et al.* (1988) found that the spawning season of *Scyllarides latus* in the southeastern Mediterranean is different, to a certain extent, from the spawning season observed for the same species by Martins (1985) in the Azores, because of faster increase of water temperature in the spring in the southeastern Mediterranean.

Adults of *S. arctus* are known from all parts of the Mediterranean Sea (Holthuis, 1991; Holthuis & Gottlieb, 1958; Stephensen, 1923). They live in relatively shallow waters preferring muddy bottom (Pippitone, *personal communications*). While adults are reported from Israeli and Egyptian coasts (Holthuis & Gottlieb, 1958), no phyllosoma were found close to these coasts (Fig. 2). Most larvae were caught far away with two found as far as about 260 km off the coast.

Larvae (Fig. 2) were sampled mostly in the eddy south of Crete (cold-core eddy), Mersa Matruh and its northern neighbor gyre (south-east of Crete) and Shikmona eddy (south of Cyprus). Only two phyllosoma were found away from any eddy structure south of Crete. However, since most cruises were aimed for measurements of physical and chemical characteristics of eddies, the sampling pattern of larvae may be imbalanced. It is therefore suggested to extend the sampling range of the present preliminary study also to areas away from eddies.

Drifter experiments south of Crete showed that buoys that had been trapped for days or weeks in eddies moved for unknown reasons to the eddy boundaries, left the eddies, but became trapped once more, by neighboring eddies (A. Hecht, *personal communications*). The planktonic life of phyllosomes lasts several months. This implies an increased probability that they will be trapped in eddies while they drift away from the coast. Obviously there is a "trade off" between the advantage of reaching uninhabited coasts and the risk of being lost at sea. The amount of time larvae actually spend in a

certain eddy has not been calculated and it is not known where they emerge. Yet, this explains the high dispersal of larvae. Long planktonic larval-life and high dispersal often correlate with a broad niche breadth in the adults. High larval dispersal reduces intraspecific competition that is of particular importance in environments with highly limited resources. The data of the present preliminary study is based on a relatively small number of phyllosomes. There is a clear need to expand the sample size, spatial and temporal scope of the coverage in future studies to verify the trends suggested here.

#### ACKNOWLEDGMENTS

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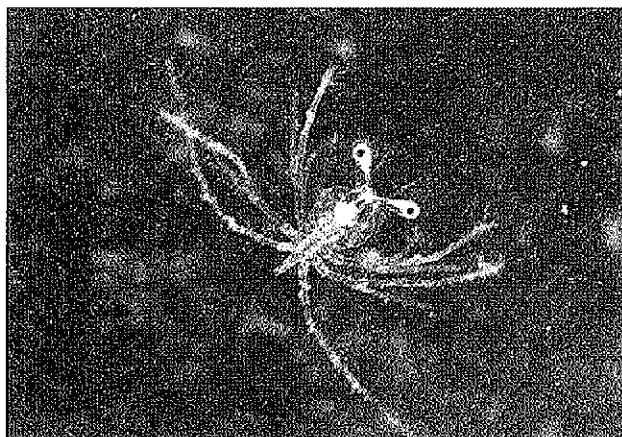


Fig. 3: Phyllosoma larva of the broad lobster *Scyllarus arctus* (Photo: E. Spanier).

Sl. 3: Larva filozoma raka vrste *Scyllarus arctus* (Foto: E. Spanier).

## POJAVLJANJE LARV RAKA SCYLLARUS ARCTUS (CRUSTACEA, DECAPODA, SCYLLARIDAE) V VZHODNEM SREDOZEMLJU - PREDHODNI REZULTATI

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#### POVZETEK

Avtorja sta s planktonsko mrežo lovila in vzorčevala filozome raka nagajivca *Scyllarus arctus* (Crustacea: Decapoda: Scyllaridae) v vzhodnem Sredozemlju. Na osnovi vzorčenja sta pripravila shemo za ločevanje med

razvojnimi stadiji larv, z opisi značilnosti stadijev filosom od 3-12. Filosome preučevane vrste so bile najdene med skoraj vsakim vzorčenjem v teku leta in v vzorcih so bili zastopani skoraj vsi stadiji. Dobljeni zgodnji razvojni stadiji larv kažejo na to, da dristitveno obdobje poteka predvsem med februarjem in aprilom ter med julijem in septembrom. Večina larv je bila ujeta daleč od obrežja. Larve so bile vzorčene v štirih območjih s stalnimi ali ponavljajočimi se cirkulirajočimi vrtinci. Podatki teh raziskav kažejo na verjetnost, da se filosome lahko ujamejo v vrtince za razmeroma dolgo obdobje, ko jih nosi proč od obrežja. Avtorja razglabljata o možnem ekološkem pomenu teh odkritij.

**Ključne besede:** zooplankton, filosome, raki, desetonožci, medvedji raki, *Scyllarus arctus*, razširjenost, vzhodno Sredozemlje

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## POISONOUS AND VENOMOUS ORGANISMS OF THE NORTHERN ADRIATIC SEA

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### ABSTRACT

Several poisonous (toxic) and venomous species are known to live or sporadically occur in the northern part of the Adriatic Sea. Despite the fact that they generally do not represent a major health hazard, they certainly deserve our attention and knowledge about their biology, ecology and harmful substances they possess. The majority of toxic organisms that could be found in the northern Adriatic belong to a large group of single cell planktonic algae (Dinophyta). A vast number of toxic species are members of sponges (Porifera). Under certain circumstances some fish from the Scombridae family could also become toxic due to the improper storage and subsequent massive release of histamine in their bodies. Massive blooms of toxic dinoflagellates represent a major threat to human health due to the accumulation of their toxins in edible shellfish species like mussels (*Mytilus galloprovincialis*). Venomous animals (those who inject their toxins directly into the body of their victim) could be found in different groups of marine animals, most notably among coelenterates and fishes.

**Key words:** venomous organisms, poisonous organisms, human health, Northern Adriatic

### INTRODUCTION

Marine organisms are a vast source of toxic compounds with a broad spectrum of biological activities. Many are harmful to man, but only few of them can inflict serious enough envenomation/intoxication that could lead to the death of the inflicted person. In this regard, members of the dinoflagellates, cnidarians, molluscs and fishes deserve our special consideration. It is known that certain species of dinoflagellates and some diatoms cause serious, sometimes massive intoxication due to the ingestion of otherwise edible shellfish. In their tissues they accumulate harmful biotoxins that are produced during massive algal blooms and therefore become poisonous. Diarrhetic (DSP), paralytic (PSP) and neurotoxic (NSP) intoxication are produced by different dinoflagellate species, while amnesic (ASP) symptoms are caused by diatom biotoxins. Ciguatera is another well-known disease with rather bizarre neurological symptoms. It occurs in tropics and subtropics and is caused by ingestion of poisonous predatory fish. These fish accumulate biotoxins through the food web. The source of biotoxins is the toxic benthic dinoflagellate *Gambierodiscus toxicus*. Sometimes it causes massive

intoxication that is seldom fatal but could last for extended period of time (up to several months). Certain tissues of the notorious fugu fish (Tetraodontidae, puffer fish), which are considered a delicacy in Japan, are a prime source of tetrodotoxin, although this toxin could be also found in some other marine and even terrestrial organisms. The exact origin of the toxin is not known, although the growing evidence shows that certain bacteria are the source of the toxin. Tetrodotoxin blocks sodium channels in nerves and causes fatal respiratory paralysis. Venomous marine animals can inflict moderate to serious envenomation. Some of their toxins are powerful enough to kill an adult within a couple of minutes. Most venomous marine animals belong to cnidarians, molluscs, fishes and sea snakes. In this paper we will focus on the toxic and venomous organisms that inhabit the Northern Adriatic Sea.

### TOXIC ALGAE AND THEIR BLOOMS

The Adriatic has been for a long time considered relatively safe in terms of toxic marine plankton blooms. However, the increased eutrophication in the Northern Adriatic basin during the last two decades resulted in

occurrence of several toxic dinoflagellate species and their blooms which affected mariculture production (Boni *et al.*, 1990; Malej *et al.*, 1997; Sedmak & Obal, 1998). The maricultures were periodically closed and shellfish sale was temporarily banned by the public health authorities due to the serious threat to the human health. The unicellular algae implicated in the production of diarrhetic shellfish poison (DSP) mainly belong to the genus *Dinophysis* (Sedmak & Fanuko, 1991). The first documented occurrence of a massive toxic bloom in the Slovenian part of the Adriatic was in October 1984. A massive occurrence of potentially harmful *Gymnodinium* and *Alexandrium* species was detected and several gastrointestinal intoxication reported (Fanuko *et al.*, 1989; Mozetič *et al.*, 1997). From there on toxic blooms occurred almost on a regular basis. Due to the detection of biotoxins in mussel's tissue and identification of harmful toxic algae in the Slovenian part of the Adriatic in the last decade, maricultures were not temporary closed only in 1991 and 1992. In all cases toxic blooms occurred in mid or late summer or early autumn, except in 1993 when maricultures were closed from mid October to the end of November and in 1989 when production and sale of mussels were banned for almost half a year, from late September to the beginning of March 1990 (Sedmak & Obal, 1998). In 1996, two human intoxication by DSP were reported in Slovenia, while many others probably passed unnoticed because of the similarity of DSP symptoms to other gastrointestinal infections (Malej *et al.*, 1994). The shellfish species that accumulate the largest amounts of toxins are edible mussels (*Mytilus galloprovincialis*). These mussels are also the main mussels grown in maricultures. Other shellfish that appear on the fishmarkets and are commonly eaten are Pilgrim's scallops (*Pecten jacobaeus*), oysters (*Ostrea edulis*), warty venus shells (*Venus verrucosa*), and checkerboards (*Venerupis decussata*). These could also be affected by harmful toxins, but generally accumulate less toxins and are less often available on the fishmarkets for larger consumption.

Toxins implicated in DSP intoxication are acidic okadaic acid (a strong tumor promoter and protein phosphatase inhibitor), dinophysin toxin-1, -2 and -3 (DTX-1, DTX-2, DTX-3) and several polyether lactones named pectenotoxins (PTX). Another class of polyether toxins - yessotoxins (YTX) - were also found in the Adriatic mussels from the Emilia-Romagna coast (Ciminiello *et al.*, 1997). Ingestion of YTX could also induce neurological symptoms in intoxicated persons although so far, other toxins that cause amnesic (ASP), paralytic (PSP) or neurotoxic (NSP) symptoms have not been detected in the Adriatic mussels.

The periodical but regular occurrence of toxic algal blooms in the northern Adriatic is a serious threat to public health and to the local economy. It is beyond the scope of this paper to discuss problems associated with toxic algal blooms but a suitable measures of protection,

monitoring and legislature are required in order to control this phenomena (e.g. Sedmak & Obal, 1998).

### Marine sponges

Marine sponges are known to be true "chemical factories" producing an impressive number of unique substances with a broad spectrum of biological activities. Some tropical species are known to produce severe contact dermatitis and itching (Mebs, 1995; Fisher, 1978) but the majority is considered harmless and no harmful effects on man from the Adriatic sponges have been reported so far. There are, however, well documented reports from the Mediterranean on the so-called sponge divers disease which in fact occurs due to repetitive stings by an anemone (*Sagartia elegans*) attached to the sponges at the depth of 25-45 metres (Zervos, 1934; Halstead, 1988). With a decline of commercial sponge collecting, this disease became extremely rare. Treatment is symptomatic: non-ineffective but unresponsive skin reaction may respond to a short (up to 3 days) course of systemic steroid application under medical supervision.

The lack of appropriate structures for injection of toxic substances and the fact that sponges are not eaten by humans put sponges far from being considered a hazard to human health. Nevertheless, sponges are one of the prime targets in search of novel substances that might be useful in treatment of various diseases from AIDS to cancer. As an example, in aqueous extracts of just 21 northern Adriatic sponges we found hemagglutinating, haemolytic, antibiotic, cytotoxic and anticholinesterase activity (Sepčić *et al.*, 1997). With no doubt we can conclude that what we know about sponges is just a scratch under their surface. Many new and important chemical substances could be expected from their bodies in the future.

### Coelenterates

Coelenterates (Cnidaria: sea anemones, jellyfish and hydroids) represent, with no doubt, toxicologically the most important group of marine organisms. Some of their venoms are so powerful that can kill an adult within minutes. There are several members of the class that inflict upon contact painful stings with sometimes serious consequences (see Williamson & Burnett, 1995). In the Northern Adriatic there are several cnidarians that could be harmful to man, but usually envenomation is moderate and does not present a serious threat to the victim.

The most notorious example of the venomous jellyfish from the Adriatic is the massive occurrence of Mauve stinger jellyfish (*Pelagia noctiluca*) in the late seventies and early eighties (Maretić *et al.*, 1980; Maretić & Russel, 1983). This species was so abundant that represented a serious threat to the tourist economy of the



Mediterranean countries. Thousands of people were stung by this relatively small jellyfish. Most of the victims developed only local reactions, in some hyperpigmentation of the skin developed that persisted for month, and there were few reports of systemic reaction and even anaphylactic shock (Togias *et al.*, 1985).

Other potentially dangerous jellyfish that occurred along the north Italian Adriatic coast is the cubomedusa *Carybdea marsupialis* (Avian *et al.*, 1992; Rottini *et al.*, 1995). Contact with this jellyfish has been reported to cause erythematous-vesicular eruptions over the skin, accompanied by pain and a strong burning sensation. Skin lesions may also be observed in more susceptible individuals (Kokelj *et al.*, 1992, 1993).

Other species of jellyfish that are sporadically common in the Northern Adriatic are *Cotylorhiza tuberculata*, *Rhizostoma pulmo*, *Aurelia aurita*, and *Chrysaora hysoscella*. Although some reports list these species as stingers (e.g. Kokelj *et al.*, 1989), a personal experience of the author cannot confirm these reports. However, it is possible that in susceptible individuals these jellyfish may also inflict a painful sting and one should be cautious in handling them with bare hands. Most of the jellyfish venoms contain cytolysins, but they are difficult to isolate in pure form since they are extremely heat labile and prone to the denaturation from various other reasons. The ambiguity in this field of research is therefore large and no firm conclusions about the composition of jellyfish venom have been made.

Sea anemones (Actiniaria) are another representative of the cnidarians that can inflict a painful sting. Although all sea anemones contain very powerful and even lethal toxins in their nematocysts, there are only few species that can pierce human skin and cause envenomation. *Anemonia sulcata* is one such species living in shallow waters and rocky pools of the Adriatic, sometimes covering large areas. This species is photophilic and could persist even in polluted waters. Small children that often play in the rocky pools are especially prone to the envenomation since their skin and mucosa are more tender. The affected area of the skin takes on a reddened and slightly raised appearance, bearing irregularly scattered pin-head size vesicles and sometimes an edema may develop around the injured skin. On lips and child skin larger blisters can develop. The area becomes painful, particularly to touch and heat (Maretić 1975; Maretić & Russel, 1983). There are some other sea anemones that could cause unpleasant consequences upon contact with their tentacles, i.e. the already mentioned *Sagartia elegans* and two rare species whose existence in the Northern Adriatic is doubtful: *Alicia mirabilis* and *Cladastis costae*. The touch of the latter (Pelješac peninsula, Southern Adriatic, personal experience, 1987) was quite painful and a burning sensation with erythema of the hand lasted for several hours. Most sea anemones possess peptide neurotoxins

that block sodium or potassium channels in nerves. Many also possess protein cytolytic toxins that are, however, different from those found in jellyfish. No special treatment of sea anemone stings is needed. In most cases a topical ointment like Kamagel will ease the pain and the symptoms. In small children precaution is needed in order not to spread undischarged nematocysts over the body and in the vicinity of mouth and eyes.

In the case of jellyfish stings, treatment of the victim depends on species involved.

For *Pelagia* stings washing with sea (not tap) water and application of ice is recommended. If symptoms persist or worsen one should seek medical attention, and especially if signs of anaphylactic shock develop this should be done without any hesitation. In the case of a *Carybdea* sting, the remaining nematocysts should be first neutralised by vinegar and then by ice packs for pain relief. One should seek medical help if symptoms persist or worsen.

#### MOLLUSCS (MOLLUSCA)

The only toxic molluscan species in the Northern Adriatic is the Mediterranean cone snail (*Conus mediterraneus*). However, no reports exist about the composition of its venom and possible envenomation in humans. Nevertheless, one should be careful in handling this cone since some of its tropical cousins are known to possess in their venoms a vast array of peptide toxins that can easily cause human death. The Mediterranean cone is a greenish brown cone shaped snail, but its shell is often variable and covered with bryozoans.

#### ANNELIDA (POLYCHAETA)

Some of the bristle worms are capable of inflicting painful wounds by their hollow and brittle setae, filled with toxins. Such species are those from the genera *Eurythoe*, *Aphrodita* and *Hermodice*. Fire worm (*Hermodice carunculata*) is a large up to 25 cm long segmented worm. Each of the segments bears on both sides numerous white setae that are extremely fragile upon contact. According to Penner (1970), the contact with bristleworm *H. carunculata* produced pain and transient numbness of the hand when setae were broken off in the skin. The pain or stinging sensation persisted for more than 12 hours, and the numbness of the entire extremity lasted for about 30 minutes. He suggested that the setae be filled with neurotoxin, which was emptied into the wounds when the bristles broke off. *Hermodice carunculata* could be found at various depths. Because the worm is a scavenger, it could be usually found over dead marine creatures. People (except SCUBA divers) only occasionally come in close contact with this worm. Care should be exercised to avoid touching this and other polychaete worms with bare hands.

## ECHINODERMATA

Sea urchins are a nuisance well known to bathers who dare to venture into the water barefooted. Although the majority of sea urchins are not toxic, their fragile broken spines that were not entirely removed from the skin tend to get inflamed due to the bacterial infection. Granuloma and vesiculation of the skin around the broken particle are common, and sometimes surgical approach is needed to remove the spine. In the Adriatic the usual culprits are the violet sea urchin (*Paracentrotus lividus*) and black sea urchin (*Arbacia lixula*). The latter is less common, but contact with its extremely fragile spines tends to be more painful and broken particles are more difficult to remove. The only sea urchin in the Adriatic possessing venomous glands is the one that could be handled with bare hands without any consequences. *Sphaerechinus granularis* belongs to the Toxopneustidae family of sea urchins, which are toxic. *S. granularis* is no exception, but its venomous pedicellaria (Peres, 1950) are too weak to pierce the human skin, its spines are blunt and difficult to break. Another potentially dangerous species because of its extremely long spines is the Mediterranean diadema urchin (*Centrostephanus longispinus*). However, this sea urchin lives only in the southern part of the Adriatic. It is unlikely for us to encounter its spines since its habitat is below 50 m. This species belongs to the diadema sea urchin family whose members are a real threat to the unaware tourists in the tropics.

Among other echinoderms sea stars and holothurians are known to possess or excrete different toxic substances with predominant hemolytic activity. The majority of them are saponins, holothurin being probably the most examined substance of this class (Habermehl & Volkwein, 1971). The noxious taste of these compounds probably repel potential predators, but they do not affect human beings.

**Fig. 1:** Snake locks anemone (*Anemonia sulcata*) possesses several neurotoxins. A touch by its tentacles could be painful, especially with small children.

**Sl. 1:** Voščena morska vetrnica (*Anemonia sulcata*) vsebuje številne nevrotoksine. Dotik njenih lovk je lahko boleč, zlasti pri majhnih otrocih.

**Fig. 2:** Compass jellyfish (*Chrysaora hysoscella*) is quite common, but its stings are very mild.

**Sl. 2:** Kompasni klobučnjak (*Chrysaora hysoscella*) je razmeroma pogost, dotik z lovkami pa ne pušča hujših posledic.

**Fig. 3:** Mediterranean cone shell (*Conus mediterraneus*) is the only venomous gastropod in the Mediterranean.

**Sl. 3:** Sredozemski stožec (*Conus mediterraneus*) je edina strupena vrsta polža v Sredozemlju.

**Fig. 4:** Purple sea urchin (*Sphaerechinus granularis*) is the only venomous sea urchin in the Adriatic. However, its spines are blunt and venomous pedicellaria too weak to pierce the human skin.

**Sl. 4:** Pegasti ježek (*Sphaerechinus granularis*) je edini strupeni morski ježek v Jadranu. Ker pa so njegove bodice tope, ščipci pa šibki, človeku ni nevaren.

**Fig. 5:** Weevers are without much doubt the most venomous fish in the Mediterranean. Streaked weever (*Trachinus radiatus*) can reach the length of 50 cm and should be treated with respect. Envenomation is extremely painful, but fortunately its venom is thermolabile.

**Sl. 5:** Morski zmaji so nedvomno najbolj strupene sredozemske ribe. Črnohlavi morski zmaj (*Trachinus radiatus*) lahko doseže do 50 cm dolžine, zato moramo biti ob srečanju z njim še posebno previdni. Vbod morskega zmaja je ekstremno boleč, k sreči pa je strup termolabilen.

**Fig. 6:** A related species is the greater weever (*Trachinus draco*). In the Northern Adriatic this species is more abundant but is usually smaller. Its venom is equally efficient as the venom of its relative, the streaked weever. Greater weevers are usually buried in the sand.

**Sl. 6:** Sorodna vrsta je morski zmaj (*Trachinus draco*). V severnem Jadranu je ta vrsta bolj pogosta, vendar doseže nekoliko manjšo velikost. Strup morskega zmaja je enako učinkovit kot strup sorodnega črnohlavega morskega zmaja. Morski zmaji so pogosto popolnoma vkopani v pesek.

**Fig. 7:** Scorpion fish are a common sight underwater, but can be easily overlooked due to their cryptic coloration while lying motionless on the sea bottom. There are several species with venomous spines that can inflict painful wounds, although less serious compared to the weevers stings. The biggest species in the Adriatic is the red scorpionfish (*Scorpaena scrofa*).

**Sl. 7:** Z bodikami se pod vodo pogosto srečamo, čeprav jih zaradi njihove barvne prilagojenosti okolju in nepremičnemu ležanju na dnu velikokrat tudi spregledamo. Poznamo nekaj vrst, vse imajo strupene bodice, ki lahko povzročijo boleče rane, čeprav so te manj hude od vbodov z bodicami morskih zmajev. Največja bodika v Jadranu je rdeča bodika (*Scorpaena scrofa*).

**Fig. 8:** Sting rays and eagle rays possess one or two long venomous spines protruding from the base of their tails. Encounters with these fishes are, except on fishing boats, rather rare. Common sting ray (*Dasyatis pastinaca*) is the most common stingray in the Adriatic. It can reach the length of up to 1.5 m. (All photos by T. Turk)

**Sl. 8:** Strupene ribe v Jadranu so še morski biči in morski golobi. Obe skupini rib imata po eno ali dve dolgi strupeni bodici, ki štrlita iz repnega korena. Srečanja s temi ribami, razen na ribiških ladjah, so redka. Na sliki je morski bič (*Dasyatis pastinaca*). Največji ulovljeni osebek je bil dolg 1,5 m. (Vse fotografije: T. Turk)





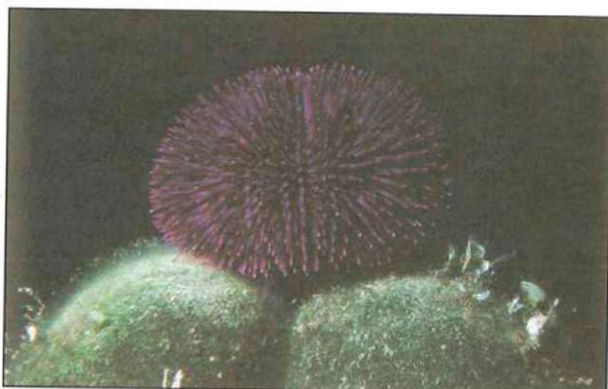
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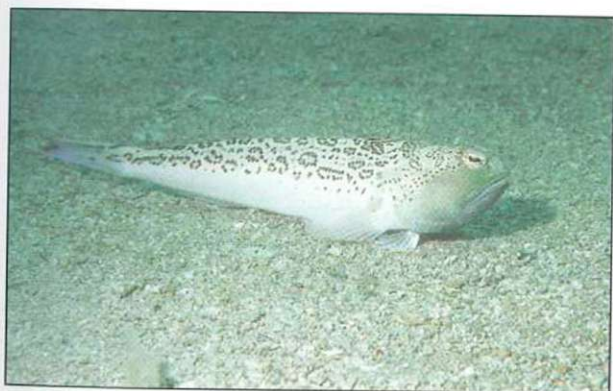
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## FISH

## Venomous fish

Venomous fish are probably of the greatest medical importance in the Northern Adriatic since they are frequently encountered by fishermen, divers and bathers. Without much doubt the most venomous fish of the Mediterranean are weever fishes. There are four species living in the Adriatic: very common greater weeverfish *Trachinus* (recently renamed to *Echichthys draco*, fairly common streaked keever (*T. radiatus*), less common spotted weever (*T. araneus*), and very rare lesser weever (*T. vipera*). The latter is also the smallest but considered the most venomous. Weevers are small to medium sized fish, the largest documented one caught near Pula was a specimen of *T. radiatus*, measuring 53 cm and weighting 1550 g (Maretić & Vejnović, 1990). They are benthic fish lying motionless on the sea bed; frequently they bury themselves into the sand with eyes, head and dorsal and opercular spines exposed. They live at various depths, but in summer when spawning takes place, they could be found in very shallow water. The common features of all weevers are their venomous spines of the dorsal fin (D1) and an additional dagger-like opercular spine on each side of the head. Grooved spines are lined with glandular cells that produce venom. The isolation of fish toxins from crude venom preparations is one of the most challenging problems in toxinology. Weevers are no exception in this regard. Toxic components of the venom are extremely unstable at room temperature. It was not until 1992 when dracotoxin, a main toxic component of crude *T. draco* venom preparation, has been isolated. Dracotoxin is 105 Kda hemolytic protein showing high affinity for rabbit red blood cells. It causes depolarisation of rat brain particles and is lethal to mice (Chhatwal & Dreyer, 1992a, 1992b). It is quite possible that dracotoxin possesses also additional biological activities that may be responsible for the clinical picture seen in human envenomations.

Envenomation with weevers most often occurs in inexperienced tourist fishermen who are not aware that grabbing and handling a struggling weever on the hook line may end with serious consequences. Less common, but still important, are accidents in sandy shallow waters where bathers are swimming and wading barefooted on the sea bed and being stung by stepping on the buried weever. In the Pula Medical Centre, out of 257 patients stung by different species of weevers only 41% were local people, while the rest were tourists (Maretić, 1982). The weeverfish sting is extremely painful, victim may scream of the excruciating pain. The instantaneous burning pain is probably due to the large amounts of 5-hydroxytryptamine and histamine in the venom (Carlisle, 1962; Chhatwal & Dreyer, 1992b). Soon pain comes to involve the entire affected limb and within 30 min or so increases to reduce the patient to writhing and some-

times screaming incoherence (Halstead, 1988). Local swelling and erythema quickly follow and in neglected wounds significant local tissue damage, protracted morbidity of the limb and secondary bacterial infection may occur. Death cases are documented (Skeie, 1962a, 1962b; Carlisle, 1962; Maretić, 1988) but at least three of them were due to delayed septicemia.

Fortunately, because venom components are extremely heat sensitive and labile, hot water immersion is an effective remedy for weeverfish (as well as other venomous fish) stings. The temperature of the water should be comfortable enough for the patient, hot enough to provide relief but not too hot to cause burns. In more serious cases an antivenin against *Trachinus*, *Scorpaena* and *Uranoscopus* that effectively relieve the symptoms within minutes is available, produced by the Imunološki institut in Zagreb.

Stargazers (*Uranoscopus* spp.) are closely related to weevers but the reports about their toxicity are ambiguous. They have two sharp dorsal spines and an opercular spine, but according to Halstead (1988) they do not possess venomous glands, therefore they are considered nonvenomous. However, Gerhardt and Delange (1999) claim that the Mediterranean stargazer (*Uranoscopus scaber*) possesses venomous spines. In man, accidental slings provoke acute pains and twinges that last, if untreated, for about 24 hours. Nevertheless, stargazer venom seems to be far less toxic than that of weevers or the scorpion fish.

Scorpion fishes (Scorpaenidae) are well known for their venomous spines in their front dorsal fin and numerous opercular spines. Scorpion fish are masters of camouflage and lie motionless on the sea bottom. According to Maretić (1982a), most accidents occur with housewives who clean the fish and accidentally get stung. There are four species living in the Northern Adriatic: black scorpionfish (*Scorpaena porcus*), red scorpionfish (*S. scrofa*), small red scorpionfish (*S. notata* *S. usiulata*) and Madeira rockfish (*Sebastes maderensis*). Symptoms of envenomation due to the sting are painful and similar to those of weevers, but generally milder. Recommended treatment is the same as in weever's sting.

It is quite unlikely to get stung by one of the members of eagle rays (Myliobatidae) or stingrays (Dasyatidae). Since this animals can reach considerable size one should be aware of their venomous, harpoon like, barbed spines (transformed dorsal fins) protruding from their tails. In large specimens these spines can reach up to 20 cm and are a respectable weapon that is not only venomous but can also cause deep traumatic injuries. Because these fishes are cautious and usually live in greater depths, accidents in the Adriatic are very rare. However, in certain part of the world, like in California, they contribute to the majority of fish envenomation. The major culprit there is the stingray *Urobatis halleri* (Maretić, 1982a). Eagle ray or stingray slings cause acute



pain, redness and edema around the wound. General symptoms are malaise, nausea and sweating. Anxiety, salivation, vomiting, diarrhoea, troubles in respiration, blurred vision, paresthesias and shock have also been described (Halstead, 1970). Treatment is symptomatic, immersion in hot water is recommended for pain relief, but larger wounds should be also treated surgically. To avoid accidents with stingrays and eagle rays, great care should be exercised, especially with large caught specimens that can trash around with their tail and cause injuries of vital organs.

### Fish poisoning

Moray eels, to the contrary of their fierce and evil look and popular belief that they are venomous, do not possess any venom glands. Nevertheless, their bite could cause serious bacterial infection. Mediterranean moray eel (*Muraena helena*) that is rare in the Northern Adriatic, conger eel (*Conger conger*), and eel (*Anguilla anguilla*) are, however, cryptotoxic since they have poisonous blood.

Another form of fish poisoning (ichthyotoxism) is also possible by ingesting certain fish of Scombridae family which is, however, due to the improper storage of the catch and not to their endogenous toxins. Scombrotism or scombroid fish poisoning is due to the large

content of histamine released from the flesh of mackerels and other fish of the Scombridae family. The reason is improper storage of fish that enables bacteria in releasing histamine from the fish muscles. A peppery taste of the fish indicates a high level of histamine. Symptoms are typical of histamine poisoning, including headache, dizziness, nausea, vomiting, generalised erythema and urticaria, followed by diarrhoea, extensive pruritus, and in severe cases bronchospasm and respiratory distress. Shock and even death may follow in untreated severe cases (Taylor *et al.*, 1989). Treatment is carried out with antihistaminic drugs. In the former Yugoslavia a case of massive scombrotic poisoning was reported in 1981 (Maretić, 1982b). Scombrotism is an important public health issue and canned fish may also be implicated (Murray *et al.*, 1982).

### CONCLUSIONS

We can conclude that marine organisms in the Northern Adriatic usually do not represent a serious threat to public health. Nevertheless, the knowledge about their biology, ecology and harmful substances they possess is important in order to act properly when individuals or even larger population are affected by their toxins or venoms.

## STRUPENI ORGANIZMI SEVERNEGA JADRANA

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### POVZETEK

V severnem Jadranu živi občasno ali stalno nekaj vrst strupenih morskih organizmov. Čeprav ne pomenijo resne nevarnosti za zdravje ljudi, si zaslužijo našo pozornost in znanje o njihovi biologiji, ekologiji in strupenih snoveh, ki jih najdemo bodisi v njihovih telesih bodisi v strupnih žlezah. Veliko večino organizmov v vodah severnega Jadrana, ki v določenih razmerah lahko postanejo strupeni, prištevamo k drobnim enoceličnim planktonskim oklepnim bičkarjem (Dinophyta). Množična cvetenja dinoflagelatov so najhujša grožnja zdravju ljudi, saj se ti toksini kopičijo v tkivih školjk, kot so npr. klapavice (*Mytilus galloprovincialis*). Veliko toksičnih snovi vsebujejo tudi spužve (Porifera). Tu in tam lahko postanejo strupene tudi nekatere ribe iz družine skuš (*Scombridae*), kar pa je v glavnem posledica nepravilnega shranjevanja ulova in posledično velike vsebnosti histamina v tkivu ujetih rib. Tiste strupene živali, ki imajo strupni aparat in strup direktno vbrizgajo v telo žrtve, spadajo v različne skupine, tudi v severnem Jadranu pa jih je največ med ožigalkarji in ribami.

**Ključne besede:** strupeni organizmi, zdravje ljudi, severni Jadran

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## I MOLLUSCHI DEL LITORALE MARINO DI CERVERA (Parenzo, Istria)

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## RIASSUNTO

Tra l'autunno del 1995 e l'estate del 1998, si sono condotti alcuni studi sulla malacofauna del litorale di Cervera (Črvar), località situata nelle vicinanze di Parenzo (Poreč). In modo più specifico sono stati determinati i Molluschi raccolti all'interno della insenatura di Porto Bussola (Busuja-Porat), sui fondali antistanti il litorale settentrionale della baia omonima e lungo la costa stessa. In totale sono state identificate 395 specie, tale indice di biodiversità è stato confrontato con altri risalenti a lavori sia di inizio secolo (Vatova, 1928), sia più recenti (Passamonti et al., 1993; Vio & De Min, 1996) e risulta essere elevato soprattutto in rapporto alla limitata estensione dell'area considerata, confermando la buona situazione ambientale dell'Adriatico Settentrionale e della costa istriana in modo particolare. Si teme comunque che l'incremento del turismo porti non solo alla diffusione di campeggi e posti barca, ma anche alla cementazione di vasti tratti di litorale con un conseguente impatto biologico negativo.

**Parole chiave:** Mollusca, check-list, Istria, Alto Adriatico

## INTRODUZIONE

Sin dalla fine del secolo scorso molti ricercatori hanno studiato la fauna marina dell'Alto Adriatico e dell'Istria in modo particolare: fra questi Stossich (1879-80) e Vatova (1928 e 1949) vanno sicuramente ricordati.

Negli ultimi decenni, inoltre, sono state descritte le biocenosi bentoniche dell'Adriatico Settentrionale (Aleffi et al., 1995; Orel et al., 1981/2, 1987) e recentemente sono stati pubblicati lavori riguardanti i molluschi (Vio et al., 1981; Vio & De Min, 1996; De Min & Vio, 1997, 1998).

Volendo approfondire la conoscenza della malacofauna dell'Alto Adriatico, nel periodo compreso tra l'autunno del 1995 e l'estate del 1998, sono state effettuate diverse osservazioni sui molluschi marini della costa istriana a Nord della città di Parenzo (Poreč).

L'area presa in esame interessa l'insenatura di P.to Bussola (Busuja-Porat), la penisola omonima che la protegge dal mare aperto ed il litorale a Nord della punta stessa ed è stata scelta come fonte di studio sia per la varietà di ambienti presenti, sia per la configurazione geografica che la espone all'azione di venti diversi (Fig. 1).

## MATERIALE E METODI

I risultati presentati in questo lavoro sono stati ottenuti analizzando sia il detrito spiaggiato, sia i molluschi raccolti in immersione.

Lungo il litorale dell'area studiata, infatti, sono stati prelevati, soprattutto nei mesi autunno-invernali, diversi campioni di detrito spiaggiato, per identificare le specie di molluschi accumulate dal moto ondoso. È opportuno considerare che, in questa regione, i venti del terzo-quarto quadrante (ponente, maestrale) hanno poca rilevanza poiché raggiungono la massima intensità nel periodo compreso tra maggio ed agosto. Tra i venti boreali, invece, soltanto la tramontana, che è presente talvolta tra ottobre e febbraio, può provocare violente tempeste. Lo scirocco, che soffia da SE e più raramente il libeccio, che proviene da SW, risultano essere molto importanti per l'accumulo lungo il litorale di detriti vari e di conchiglie, dato che sollevano violente ondate che sconvolgono il fondale e si infrangono contro la costa.

Molto del materiale malacologico analizzato è stato raccolto dopo queste mareggiate ed è stato determinante per una conoscenza più approfondita delle biocenosi litorali antistanti.

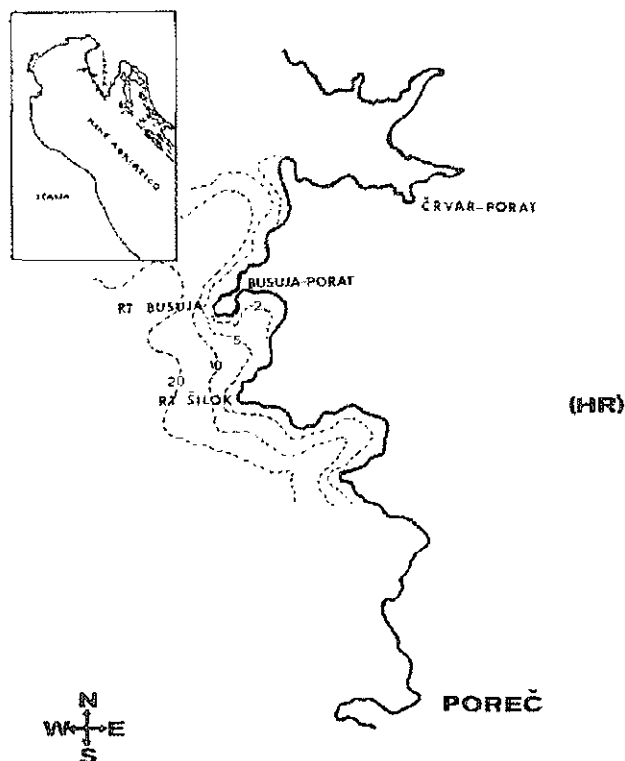


Fig. 1: Area di campionamento.  
Sl. 1: Območje vzorčevanja.

Si sono effettuate anche diverse immersioni in apnea e per mezzo di autorespiratore (ARA), durante le quali si è prelevato del detrito dalle pozze e dai canali formati sia tra le praterie di fanerogame marine, particolarmente sotto costa, sia tra la roccia calcarea, soprattutto più al largo.

Questo materiale è stato successivamente filtrato tramite un setaccio con rete a maglie di 1 mm di lato, per separarlo dalla parte pelitica.

Si è ritenuto inoltre opportuno asportare limitate superfici di substrato duro, popolate dalla biocenosi delle Alge Fotofile (A.P.) sia esposte alla luce, sia situate in posizione sciafila, per campionare i micromolluschi epifiti.

Durante tutti i rilievi subacquei, i Molluschi immediatamente classificabili, sono stati segnalati su delle tavolette di plastica, onde minimizzare il danno biologico, mentre le specie dubbie sono state prelevate e fissate in una soluzione al 5% di aldeide formica in acqua di mare per un'analisi più approfondita di laboratorio; si è seguito lo stesso procedimento per le specie appartenenti ai piani bentonici sopralitorale e mesolitorale.

I micromolluschi e gli Opisthobranchi sono stati determinati con uno stereomicroscopio Olympus SZ 40 ed alcune specie interessanti sono state fotografate con lo stesso.

Per quanto concerne la sistematica e la classificazione delle specie appartenenti alla famiglia Terebratulidae sono state consultate le pubblicazioni di Roch (1940) e di Munari (1974).

La nomenclatura presentata è quella pubblicata da Sabelli *et al.* (1990) nel "Catalogo Annotato dei Molluschi Marini del Mediterraneo", mentre i termini binomici riportati si riferiscono al lavoro di Peres & Picard (1964).

## RISULTATI

### Area studiata

L'Istria meridionale è rappresentata, dal punto di vista geologico, da serie ben definite di calcari; quella più antica appartiene al Giurassico e nella parte inferiore è caratterizzata da calcare a brachiopodi (*Rhynchonella*) a cui seguono calcari coralligeni ed oolitici, depositatisi all'epoca in un mare poco profondo ed attualmente affioranti in diverse aree soprattutto lungo la costa, in corrispondenza di quelle zone in cui i calcari cretacei sono stati maggiormente degradati dagli agenti atmosferici. Alla fine del Cretaceo, infatti, si svilupparono calcari a bivalvi (Rudiste ed Ippuriti), che subirono una sommersione nell'Eocene, periodo geologico durante il quale si depositarono calcari nummulitici (Alveoline, Nummuliti) dello spessore di una quindicina di metri, che vennero in seguito ricoperti da strati di marna ed arenaria.

Il corrugamento oligocenico, benchè attenuato per quel che riguarda l'Istria meridionale, causò una graduale emersione che diede origine ad un ampio dosso, dolcemente ondulato - pianeggiante, che venne eroso, corroso ed inciso dagli agenti dinamici. In tal modo le formazioni calcaree affiorarono e, per dissoluzione della roccia stessa, si ricoprirono di un velo di terra rossa, il cui accumulo si incrementò notevolmente dopo l'abbassamento del livello del mare, che favorì un'ulteriore emersione della regione con un conseguente aumento dell'area esposta all'erosione superficiale (Vatova, 1928).

### Il fondo marino

L'insenatura di Porto Bussola presenta nella parte settentrionale ed occidentale, una riva costituita da lastroni calcarei fessurati, mentre il lato orientale è caratterizzato da una spiaggia ciottolosa che delimita il campeggio vicino. Pur avendo l'imboccatura rivolta al mare, la baia è in larga parte riparata dai venti meridionali da P.ta Raguzzi (Rt. Silok) e permette un sicuro ormeggio alle imbarcazioni da diporto.

I piani sopralitorale e mesolitorale, sebbene limitati in altezza, sono notevolmente estesi in lunghezza, soprattutto considerato il fatto che sono soggetti ad una

escursione di marea ridotta; queste fasce presentano grossi accumuli di materiale spiaggiato, dove vivono specie caratteristiche delle biocenosi dei Residui a Rapida e Lenta Dissecazione (R.R.D., R.L.D.)

Per quel che concerne l'infralitorale, nella parte orientale vicino alla riva, è caratterizzato da un fondale di sabbia fine, che ospita la biocenosi delle Sabbie Fini Ben Calibrate (S.F.B.C.), mentre nelle vicinanze di un piccolo approdo, situato nell'angolo più interno della baia, in corrispondenza di una sorgente carsica, diviene pelitico: in questo ambiente vivono elementi tipici delle Lagune Euriterme ed Eurialine (L.E.E.).

Procedendo verso il largo, dopo i due metri di profondità, la sabbia presenta granulometria diversa ricca sia di materiale organico, sia di frazioni pelitiche. Questo tipo di sedimento si accumula tra i rilievi rocciosi, permettendo l'instaurarsi della biocenosi delle Sabbie Fangose di Moda Calma (S.V.M.C.), con una facies a *Cymodocea nodosa*.

Le fanerogame marine scompaiono pressoché totalmente alla profondità di 5-6 metri in direzione dell'entrata di P.to Bussola e vengono sostituite da formazioni rocciose che continuano verso il largo.

La penisola è caratterizzata da un infralitorale ad Alghe Fotofile (A.P.) con predominanza di una facies precoralligena, questo perché le rocce calcaree che la costituiscono, non solo sono ampiamente fessurate, ma anche ricche di aree sciafile soprattutto alla base dei massi.

Aggirando la penisola e procedendo verso settentrione, le rocce calcaree sommerse si presentano più levigate e si alternano a canali scavati dall'idrodinamismo, ai cui lati crescono dei piccoli prati di *Cymodocea*; in questi canali si rinvennero molte specie appartenenti alla biocenosi delle Sabbie Grossolane sottoposte alle Correnti di Fondo (S.G.C.F.).

Più al largo, il fondale raggiunge la profondità di 20 metri ed è caratterizzato da sabbia grossolana che si arricchisce sempre più di elementi pelitici, si passa in tal modo dalla biocenosi del Detritico Costiero (D.C.), a quella del Detritico Fangoso (D.E.) fino a trovare alcune specie appartenenti ai Fanghi Terrigeni Costieri (V.T.C.).

#### Lista dei molluschi rinvenuti nella zona di Cervera (C.rvar)

Nella seguente tabella viene presentata la lista dei molluschi rinvenuti sia viventi, sia presenti nel detrito con la sola parte conchigliare; in quest'ultimo caso sono state considerate valide anche le specie che presentavano unicamente frammenti di guscio, ma chiaramente riconoscibili.

(\* molluschi rinvenuti viventi)

(C = molluschi presenti nel Circolitorale)

#### Classe Polyplacophora Gray J. E., 1821

1. *Lepidopleurus cajetanus* (Poli, 1791)\*
2. *Ischnochiton rissoi* (Payraudeau, 1826)\*
3. *Callochiton septemvalvis euplaeae* (Costa O.G., 1829) C
4. *Lepidochitona cinerea* (Linné, 1767)\*
5. *Lepidochitona corrugata* (Reeve, 1848)\*
6. *Chiton corallinus* (Risso, 1826)\* C
7. *Chiton olivaceus* Spengler, 1797\*
8. *Acanthochitona fascicularis* (Linneo, 1767)\*

#### Classe Gastropoda Cuvier, 1797

9. *Patella caerulea* Linné, 1758\*
10. *Patella ulyssiponensis* Gmelin, 1791\*
11. *Smaragdia viridis* (Linné, 1758)
12. *Diodora gibberula* (Lamarck, 1822)\*
13. *Diodora graeca* (Linné, 1758)\*
14. *Diodora italica* (DeFrance, 1820)\*
15. *Emarginula adriatica* Costa O.G., 1829\*
16. *Emarginula octaviana* Coen, 1939\*
17. *Emarginella huzardi* (Payraudeau, 1826)\*
18. *Emarginula sicula* Gray, 1825
19. *Scissurella costata* D'Orbigny, 1824
20. *Anatoma crispata* Fleming, 1828
21. *Haliotis tuberculata lamellosa* Lamarck, 1822\*
22. *Clanculus corallinus* (Gmelin, 1791)\*
23. *Clanculus cruciatus* (Linné, 1758)\*
24. *Clanculus jussieui* (Payraudeau, 1826)\*
25. *Calliostoma conulus* (Linné, 1758)\*
26. *Calliostoma laugierii laugierii* (Payraudeau, 1826)\*
27. *Calliostoma zizyphinum* (Linné, 1758) C
28. *Gibbula albida* (Gmelin, 1791)\*
29. *Gibbula ardens* (Von Salis, 1793)\*
30. *Gibbula magus* (Linné, 1758) C
31. *Gibbula adansonii adansonii* (Payraudeau, 1826)\*
32. *Gibbula adriatica* (Philippi, 1844)\*
33. *Gibbula turbinoides* (Deshayes, 1835)
34. *Gibbula fanulum* (Gmelin, 1791)\*
35. *Gibbula guttadauri* (Philippi, 1836) C
36. *Gibbula varia* (Linné, 1758)\*
37. *Gibbula divaricata* (Linné, 1758)\*
38. *Gibbula rarilineata* (Michaud, 1829)\*
39. *Gibbula umbilicaris* (Linné, 1758)\*
40. *Monodonta articulata* Lamarck, 1822\*
41. *Monodonta mutabilis* (Philippi, 1846)\*
42. *Monodonta turbinata* (Von Born, 1778)\*
43. *Chelandella miliaris* (Brocchi, 1814) C
44. *Jujubinus exasperatus* (Pennant, 1777)\*
45. *Jujubinus striatus striatus* (Linné, 1758)\*
46. *Jujubinus gravinae* (Dautzenberg, 1881) C
47. *Homalopoma sanguineum* (Linné, 1758)



48. *Skenea catenoides* (Monterosato, 1877)  
 49. *Tharsiella depressa* (Granata-Grillo, 1877)  
 50. *Tricolia pullus pullus* (Linné, 1758)\*  
 51. *Tricolia speciosa* (Von Muehlfeldt, 1824)  
 52. *Tricolia tenuis* (Michaud, 1829)  
 53. *Bolma rugosa* (Linné, 1767)\*  
 54. *Cerithium alucaster* (Brocchi, 1814)\* C  
 55. *Cerithium rupestre* Risso, 1826\*  
 56. *Cerithium vulgatum* Bruguiere, 1792\*  
 57. *Bittium jadertinum* (Brusina, 1875)\*  
 58. *Bittium lacteum lacteum* (Philippi, 1836)  
 59. *Bittium latreillii* (Payraudeau, 1826)\*  
 60. *Bittium reticulatum* (Da Costa, 1778)\*  
 61. *Bittium scabrum* (Olivi, 1792)\*  
 62. *Cerithidium submamillatum* (De Rayneval & Ponzi, 1854) C  
 63. *Diala varia* Adams A., 1861 C  
 64. *Fossarus ambiguus* (Linné, 1758)  
 65. *Turritella communis* Risso, 1799 C  
 66. *Littorina neritoides* (Linné, 1758)\*  
 67. *Eatonina cossurae* (Calcara, 1841)\*  
 68. *Eatonina fulgida* (Adams J., 1797)\*  
 69. *Rissoa decorata* Philippi, 1846  
 70. *Rissoa fraunfeldiana* Brusina, 1868\*  
 71. *Rissoa guerinii* Récluz, 1843\*  
 72. *Rissoa labiosa* (Montagu, 1803)\*  
 73. *Rissoa lia* (Monterosato, 1884)  
 74. *Rissoa monodonta* Philippi, 1836\*  
 75. *Rissoa similis* Scacchi, 1836\*  
 76. *Rissoa splendida* Eichwald, 1830\*  
 77. *Rissoa variabilis* (Von Muehlfeldt, 1824)  
 78. *Rissoa ventricosa* Desmarest, 1814  
 79. *Rissoa violacea violacea* Desmarest, 1814  
 80. *Alvania aspera* (Philippi, 1844)  
 81. *Alvania beani* (Hanley in Thorpe, 1844)  
 82. *Alvania cancellata* (Da Costa, 1778)  
 83. *Alvania cimex* (Linné, 1758)\*  
 84. *Alvania discors* (Allan, 1818)\*  
 85. *Alvania geryonia* (Nardo, 1847)\*  
 86. *Alvania lactea* (Michaud, 1832)  
 87. *Alvania lanciae* (Calcara, 1841)  
 88. *Alvania lineata* Risso, 1826\*  
 89. *Alvania mamillata* Risso, 1826  
 90. *Alvania rudis* (Philippi, 1844)  
 91. *Alvania beniamina* (Monterosato, 1888)  
 92. *Alvania semistriata* (Montagu, 1808)\*  
 93. *Alvania carinata* (Da Costa, 1778)  
 94. *Manzonina crassa* (Kanmacher, 1798)  
 95. *Manzonina weinkauffi jacobusi* Oliverio, Amati & Nofroni, 1986 C  
 96. *Peringiella elegans* (Locard, 1892)  
 97. *Pusillina inconspicua* (Alder, 1844)  
 98. *Pusillina marginata* (Michaud, 1832)  
 99. *Pusillina munda* (Monterosato, 1884)  
 100. *Pusillina parva* (Da Costa, 1778)\*  
 101. *Pusillina philippi* (Aradas & Maggiore, 1844)\*  
 102. *Pusillina radiata* (Philippi, 1836)\*  
 103. *Setia turriculata* (Monterosato, 1884)\*  
 104. *Pisinna glabrata* (Von Muehlfeldt, 1824)  
 105. *Rissoina bruguieri* (Payraudeau, 1826)  
 106. *Paludinella littorina* (Delle Chiaje, 1828)\*  
 107. *Assiminea grayana* Fleming, 1828  
 108. *Barleeia unifasciata* (Montagu, 1803)  
 109. *Caecum auriculatum* De Folin, 1868\*  
 110. *Caecum subannulatum* De Folin, 1870\*  
 111. *Caecum trachea* (Montagu, 1803)\*  
 112. *Hydrobia acuta* (Draparnaud, 1805)\*  
 113. *Heleobia stagnorum* (Gmelin, 1803)  
 114. *Ceratia proxima* (Forbes & Hanley, 1850 ex Alder mn.)  
 115. *Hyalia vitrea* (Montagu, 1803)  
 116. *Tornus subcarinatus* (Montagu, 1803)  
 117. *Truncatella subcylindrica* (Linné, 1767)  
 118. *Megalomphalus disciformis* (Granata-Grillo, 1877)  
 119. *Aporrhais pespelecani* (Linné, 1758) C  
 120. *Calyptraea chinensis* (Linné, 1758)\* C  
 121. *Crepidula gibbosa* DeFrance, 1818\*  
 122. *Crepidula unguiformis* Lamarck, 1822 C  
 123. *Capulus hungaricus* (Linné, 1758)\* C  
 124. *Vermetus triquetrus* Bivona Ant., 1832\*  
 125. *Petalococonchus glomeratus* (Linné, 1758)  
 126. *Serpulorbis arenaria* (Linné, 1767)\*  
 127. *Lamellaria latens* (Mueller, 1776) C  
 128. *Trivia arctica* (Pulteney, 1789) C  
 129. *Naticarius stercumuscum* (Gmelin, 1791)  
 130. *Euspira guillemini* (Payraudeau, 1826)\* C  
 131. *Euspira nitida* (Donovan, 1804)\*  
 132. *Euspira macilenta* (Philippi, 1844) C  
 133. *Neverita josephina* Risso, 1826\*  
 134. *Galeodea echinophora* (Linné, 1758) C  
 135. *Alanta peronii* Lesueur, 1817 C  
 136. *Marshallora adversa* (Montagu, 1803)\*  
 137. *Monophorus perversus* (Linné, 1758)  
 138. *Cerithiopsis minima* (Brusina, 1865)\*  
 139. *Cerithiopsis nana* Jeffreys, 1867 (Fig. 2)  
 140. *Cerithiopsis tubercularis* (Montagu, 1803)\*  
 141. *Metaxia metaxa* (Delle Chiaje, 1828)  
 142. *Epitonium clathratulum* (Kanmacher, 1798)  
 143. *Epitonium commune* (Lamarck, 1822)\*  
 144. *Epitonium turtoni* (Turton, 1819)\*  
 145. *Crinophtheiros comatulicola* (Graff, 1875) C  
 146. *Ersilia mediterranea* (Monterosato, 1869) (Fig. 3)  
 147. *Melanella boscii* (Payraudeau, 1827)  
 148. *Melanella polita* (Linné, 1758)\* C  
 149. *Vitreolina curva* (Monterosato, 1874 ex Jeffreys ms.)\*  
 150. *Vitreolina incurva* (B.D.D., 1883)  
 151. *Parvioris microstoma* (Brusina, 1864)  
 152. *Bolinus brandaris* (Linné, 1758)\* C  
 153. *Hexaplex trunculus* (Linné, 1758)\*  
 154. *Muricopsis cristata* (Brocchi, 1814)\*  
 155. *Ocenebra erinaceus* (Linné, 1758)\*  
 156. *Ocenebrina aciculata* (Lamarck, 1822)\*

157. *Ocenebrina edwardsii* (Payraudeau, 1826)\*  
 158. *Trophon muricatus* (Montagu, 1803) C  
 159. *Typhinellus sowerbyi* (Broderip, 1833)\*  
 160. *Buccinum corneum* (Linné, 1758)  
 161. *Chauvetia brunnea* (Donovan, 1804)\*  
 162. *Chauvetia submamillata* (B.D.D., 1882)  
 163. *Engina leucozona* (Philippi, 1843)\*  
 164. *Pisania striata* (Gmelin, 1791)\*  
 165. *Pollia dorbignyi* (Payraudeau, 1826)\*  
 166. *Fasciolaria lignaria* (Linné, 1758)  
 167. *Fusinus rostratus* (Olivì, 1792)\* C  
 168. *Fusinus syracusanus* (Linné, 1758)\*  
 169. *Nassarius corniculus* (Olivì, 1792)\*  
 170. *Nassarius incrassatus* (Stroem, 1768)\*  
 171. *Nassarius pygmaeus* (Lamarck, 1822)\*  
 172. *Nassarius reticulatus* (Linné, 1758)\*  
 173. *Nassarius mutabilis* (Linné, 1758)\*  
 174. *Nassarius costulatus cuvieri* (Payraudeau, 1826)  
 175. *Cyclope neritea* (Linné, 1758)\*  
 176. *Columbella rustica* (Linné, 1758)\*  
 177. *Mitrella minor* (Scacchi, 1836)  
 178. *Mitrella scripta* (Linné, 1758)\*  
 179. *Vexillum ebenus* (Lamarck, 1811)\*  
 180. *Vexillum littorale* (Forbes, 1844)  
 181. *Vexillum tricolor* (Gmelin, 1790)  
 182. *Gibberula miliaria* (Linné, 1758)  
 183. *Gibberula philippi* (Monterosato, 1878)  
 184. *Granulina clandestina* (Brocchi, 1814)\*  
 185. *Mitra cornicula* (Linné, 1758)\*  
 186. *Conus mediterraneus* Hwass in Bruguiere, 1792\*  
 187. *Bela nebula* (Montagu, 1803)\*  
 188. *Bela brachystoma* (Philippi, 1844)\*  
 189. *Bela decussata* (Locard, 1897)  
 190. *Bela laevigata* (Philippi, 1836)  
 191. *Mangelia brusinae* Van Aartsen & Fehr de Wal, 1978  
 192. *Mangelia paciniana* (Calcara, 1839)  
 193. *Mangelia scabrida* Monterosato, 1890  
 194. *Mangelia smithii* (Forbes, 1840)  
 195. *Mangelia stossiciana* Brusina, 1869  
 196. *Mangelia unifasciata* (Deshayes, 1835)  
 197. *Mangelia vauquelini* (Payraudeau, 1826)  
 198. *Mangiliella bertrandii* (Payraudeau, 1826)  
 199. *Mangiliella caerulans* (Philippi, 1844)  
 200. *Mangiliella multilíneata* (Deshayes, 1835)  
 201. *Mangiliella taeniata* (Deshayes, 1835)  
 202. *Mitrolumna olivoidea* (Cantraine, 1835)  
 203. *Raphitoma echinata* (Brocchi, 1814)\*  
 204. *Raphitoma histrix* Bellardi, 1847  
 205. *Raphitoma laviae* (Philippi, 1844)  
 206. *Raphitoma linearis* (Montagu, 1803)\*  
 207. *Raphitoma purpurea* (Montagu, 1803)  
 208. *Comarmondia gracilis* (Montagu, 1803)\*  
 209. *Philbertia papillosa* Pallary, 1904  
 210. *Philbertia philberti* (Michaud, 1829)  
 211. *Omalogyra atomus* (Philippi, 1841)\*  
 212. *Ammonicera fischeriana* (Monterosato, 1869)\*  
 213. *Chrysallida delpretei* (Sullioti, 1889)  
 214. *Chrysallida dofiolum* (Philippi, 1844)  
 215. *Chrysallida emaciata* (Brusina, 1866)  
 216. *Chrysallida intermixta* (Monterosato, 1884)  
 217. *Chrysallida juliae* (De Folin, 1872)  
 218. *Chrysallida monozona* (Brusina, 1869)  
 219. *Chrysallida nanodea* (Monterosato, 1878)  
 220. *Chrysallida obtusa* (T. Brown, 1827)  
 221. *Chrysallida suturalis* (Philippi, 1844)  
 222. *Chrysallida terebellum* (Philippi, 1844)  
 223. *Euparthenia bulinea* (Lowe, 1841) C  
 224. *Folinella excavata* (Philippi, 1836)\*  
 225. *Folinella ghisottii* Van Aartsen, 1984  
 226. *Clathrella clathrata* (Philippi, 1844)  
 227. *Tragula fenestrata* (Jeffreys, 1848)  
 228. *Eulimella acicula* (Philippi, 1836)  
 229. *Anisocycla pointeli* (De Folin, 1867)  
 230. *Odostomia acuta* (Jeffreys, 1848)  
 231. *Odostomia carrozzai* Van Aartsen, 1987  
 232. *Odostomia eulimoides* Hanley, 1844  
 233. *Odostomia lukisii* Jeffreys, 1859  
 234. *Odostomia nardoi* Brusina, 1869  
 235. *Odostomia plicata* (Montagu, 1803)\*  
 236. *Odostomia scalaris* Mac Gillivray, 1843  
 237. *Odostomia striolata* Forbes & Hanley, 1850  
 238. *Odostomia turrita* Hanley, 1844  
 239. *Odostomia clavulus* (Loven, 1846)  
 240. *Odostomia conoidea* (Brocchi, 1814)  
 241. *Ondina obliqua* (Alder, 1844)  
 242. *Ondina diaphana dilucida* (Monterosato, 1884)  
 243. *Ondina vitrea* (Brusina, 1866)  
 244. *Turbonilla delicata* Monterosato, 1874  
 245. *Turbonilla acutissima* Monterosato, 1884 C  
 246. *Turbonilla jeffreysi* (Jeffreys, 1848)  
 247. *Turbonilla lactea* (Linné, 1756)  
 248. *Turbonilla obliquata* (Philippi, 1844)  
 249. *Turbonilla rufa* (Philippi, 1836)\* C  
 250. *Retusa leptoneilema* (Brusina, 1866)  
 251. *Retusa mammillata* (Philippi, 1836)  
 252. *Retusa semisulcata* (Philippi, 1836)  
 253. *Retusa truncatula* (Bruguiere, 1792)  
 254. *Cylichnina laevisculpta* (Granata-Grillo, 1877)  
 255. *Cylichnina umbilicata* (Montagu, 1803)  
 256. *Volvulella acuminata* (Bruguiere, 1792)  
 257. *Bulla striata* Bruguiere, 1792 C  
 258. *Hamynoea hydatis* (Linné, 1758)\*  
 259. *Hamynoea navicula* (Da Costa, 1778)\*  
 260. *Atys jeffreysi* (Weinkauff, 1868)  
 261. *Weinkauffia turgidula* (Forbes, 1844)\*  
 262. *Philina aperta* (Linné, 1767)\*  
 263. *Philina catena* (Montagu, 1803) C  
 264. *Cylichna crossei* B.D.D., 1886  
 265. *Cylichna cylindracea* (Pennant, 1777)\*  
 266. *Scaphander lignarius* (Linné, 1758) C  
 267. *Cavolinia tridentata* (Niebuhr, 1775) C  
 268. *Elysia flava* Verrill, 1901\*

269. *Tyrodina perversa* (Gmelin, 1791)  
 270. *Aplysia depilans* Gmelin, 1791\*  
 271. *Aplysia punctata* (Cuvier, 1803)\*  
 272. *Paradoris indecora* (Bergh, 1881)\*  
 273. *Dendrodoris grandiflora* (Rapp, 1827)\*  
 274. *Dendrodoris limbata* (Cuvier, 1804)\*  
 275. *Williamia gussonii* (Costa O.G., 1829)  
 276. *Trimusculus mammillaris* (Linné, 1758)  
 277. *Auriculinea erosa* (Jeffreys, 1830)\*  
 278. *Ovatella firminii* (Payraudeau, 1826)\*  
 279. *Ovatella myosotis* (Draparnaud, 1826)\*  
 280. *Ovatella denticulata* (Montagu, 1803)

Classe **Bivalvia** Linné, 1758

281. *Nucula nucleus* (Linné, 1758)\*  
 282. *Nuculana commutata* (Philippi, 1844)\* C  
 283. *Arca noae* Linné, 1758\*  
 284. *Arca tetragona* Poli, 1795 C  
 285. *Barbatia barbata* (Linné, 1758)\*  
 286. *Scapharca inaequivalvis* (Bruguiere, 1789)\*  
 287. *Striarca lactea* (Linné, 1758)\*  
 288. *Glycymeris glycymeris* (Linné, 1758)\*  
 289. *Glycymeris insubrica* (Brocchi, 1814)\*  
 290. *Mytilus galloprovincialis* Lamarck, 1819\*  
 291. *Mytilaster minimus* (Poli, 1795)\*  
 292. *Mytilaster solidus* Monterosato 1872\*  
 293. *Gregariella petagnae* Scacchi, 1832  
 294. *Modiolarca subpicta* (Cantraine, 1835)\* C  
 295. *Musculus costulatus* (Risso, 1826)\*  
 296. *Lithophaga lithophaga* (Linné, 1758)\*  
 297. *Modiolus barbatus* (Linné, 1758)\*  
 298. *Pinna nobilis* Linné, 1758\*  
 299. *Pecten jacobaeus* (Linné, 1758)\* C  
 300. *Aequipecten opercularis* (Linné, 1758)\*  
 301. *Chlamys multistriata* (Poli, 1795)\*  
 302. *Chlamys varia* (Linné, 1758)\*  
 303. *Chlamys glabra* (Linné, 1758)\*  
 304. *Chlamys proteus* (Dillwyn, 1817 ex Solander ms.)\*  
 305. *Spondylus gaederopus* Linné, 1758\*  
 306. *Anomia ephippium* Linné, 1758\*  
 307. *Pododesmus squamula* (Linné, 1758)\* C  
 308. *Lima lima* (Linné, 1758)\*  
 309. *Lima exilis* Wood S.V., 1839\*  
 310. *Lima hians* (Gmelin, 1791)\* C  
 311. *Limea loscombi* (Sowerby G.B.I., 1823)\* C  
 312. *Ostrea edulis* Linné, 1758\*  
 313. *Crassostrea gigas* (Thunberg, 1793)\*  
 314. *Ctena decussata* (Costa O.G., 1829)\*  
 315. *Loripes lacteus* (Linné, 1758)\*  
 316. *Lucinella divaricata* (Linné, 1758)\*  
 317. *Anodontia fragilis* (Philippi, 1836)\*  
 318. *Myrtea spinifera* (Montagu, 1803)\* C  
 319. *Chama gryphoides* Linné, 1758\*  
 320. *Pseudochama gryphina* (Lamarck, 1819)\*  
 321. *Galeomma turtoni* Turton, 1825\*  
 322. *Bornia sebetia* (Costa O.G., 1829)\*  
 323. *Lasaea rubra* (Montagu, 1803)\*  
 324. *Myseilla bidentata* (Montagu, 1803)\* C  
 325. *Hemilepton nitidum* (Turton, 1822)  
 326. *Cardita calyculata* (Linné, 1758)\*  
 327. *Glans trapezia* (Linné, 1767)  
 328. *Venericardia antiquata* (Linné, 1758)\* C  
 329. *Acanthocardia aculeata* (Linné, 1758)\* C  
 330. *Acanthocardia paucicostata* (Sowerby G.B.II, 1841)\* C  
 331. *Acanthocardia tuberculata* (Linné, 1758)\*  
 332. *Parvicardium exiguum* (Gmelin, 1791)\*  
 333. *Laevicardium crassum* (Gmelin, 1791) C  
 334. *Laevicardium oblongum* (Gmelin, 1791)\* C  
 335. *Cerastoderma edule* (Linné, 1758)\*  
 336. *Mactra stultorum* Von Born, 1778\*  
 337. *Spisula subtruncata* (Da Costa, 1778)\*  
 338. *Donacilla cornea* (Poli, 1795)\*  
 339. *Solen marginatus* Pulteney, 1799  
 340. *Ensis minor* (Chenu, 1843)\*  
 341. *Tellina tenuis* Da Costa, 1778\*  
 342. *Tellina balaustina* Linné, 1758\*  
 343. *Tellina donacina* Linné, 1758\* C  
 344. *Tellina distorta* Poli, 1791\* C  
 345. *Tellina incarnata* Linné, 1758\*  
 346. *Tellina planata* Linné, 1758  
 347. *Tellina nitida* Poli, 1791\*  
 348. *Gastrana fragilis* (Linné, 1758)\*  
 349. *Donax semistriatus* Poli, 1795\*  
 350. *Donax trunculus* Linné, 1757\*  
 351. *Psammobia fervensis* (Gmelin, 1791)\* C  
 352. *Psammobia depressa* (Pennant, 1777)\*  
 353. *Psammobia costulata* Turton, 1822  
 354. *Abra alba* (Wood W., 1802)\*  
 355. *Abra tenuis* (Montagu, 1803)\*  
 356. *Solecurtus multistriatus* (Scacchi, 1834)  
 357. *Solecurtus scopula* (Turton, 1822) C  
 358. *Solecurtus strigillatus* (Linné, 1758)\*  
 359. *Venus verrucosa* Linné, 1758\*  
 360. *Chamelea gallina* (Linné, 1758)\*  
 361. *Timoclea ovata* (Pennant, 1777)\*  
 362. *Gouldia minima* (Montagu, 1803)\* C  
 363. *Dosinia lupinus* (Linné, 1758)\*  
 364. *Dosinia exoleta* (Linné, 1758)\*  
 365. *Pitar rudis* (Poli, 1795)\* C  
 366. *Callista chione* (Linné, 1758)\* C  
 367. *Tapes decussatus* (Linné, 1758)\*  
 368. *Irus irus* (Linné, 1758)\*  
 369. *Paphia aurea* (Gmelin, 1791)\*  
 370. *Venerupis senegalensis* (Gmelin, 1791)\*  
 371. *Petricola lithophaga* (Retzius, 1786)\*  
 372. *Petricola lajonkairii* (Payraudeau, 1826)  
 373. *Mysia undata* (Pennant, 1777)\*  
 374. *Corbula gibba* (Olivi, 1792)\* C  
 375. *Lentidium mediterraneum* (Costa O.G., 1839)\*  
 376. *Gastrochaena dubia* (Pennant, 1777)\*

- 377. *Hiatella arctica* (Linné, 1767)\*
- 378. *Phoias dactylus* Linné, 1758
- 379. *Teredora malleolus* (Turton, 1822) C
- 380. *Bankia carinata* (Gray J. E., 1827) C
- 381. *Thracia convexa* (Wood W., 1815) C
- 382. *Thracia corbuloides* Deshayes, 1830 C
- 383. *Thracia papyracea* (Poli, 1791)\*
- 384. *Thracia pubescens* (Pulteney, 1799)\* C
- 385. *Thracia distorta* (Montagu, 1803)\* (Fig. 4)
- 386. *Pandora pinna* (Montagu, 1803) C
- 387. *Lyonsia norvegica* (Gmelin, 1791)\* C

Classe **Scaphopoda** Bronn, 1862

- 388. *Dentalium dentalis* Linné, 1758\*
- 389. *Dentalium inaequicostatum* Dautzenberg, 1891\* C
- 390. *Dentalium vulgare* Da Costa, 1778\*
- 391. *Fustiaria rubescens* (Deshayes, 1826)\* C

Classe **Cephalopoda** Cuvier, 1798

- 392. *Sepia elegans* Blainville, 1827 C
- 393. *Sepia officinalis* Linné, 1758\*
- 394. *Sepioida rondeletii* Leach, 1817\* C
- 395. *Octopus vulgaris* Cuvier, 1798\*

**Specie di notevole interesse**

***Cerithiopsis nana* (Fig. 2)**

Come tutte le specie appartenenti al suo genere, vive dal mediolitorale all'infralitorale fino alla profondità di 100 metri circa (Nordsieck, 1968); lo si rinviene associato a spugne, dalle quali non si allontana molto, in quanto costituiscono il suo cibo preferito (Fretter & Manly, 1977).

Secondo Palazzi (1994), per voler esser più precisi, questo gasteropode vive su *Suberites domuncula*, benchè ciò risulti essere poco documentato per il Mediterraneo. Tale affermazione deriva dal fatto che l'Autore ha potuto osservare una colonia di *Cerithiopsis nana* nella Laguna di Lanterna, a nord di Cervera. Il ritrovamento, avvenuto a bassa profondità, ha suscitato stupore soprattutto per la capacità degli esemplari, di mantenersi attaccati alla spugna con fili mucosi, nonostante il forte moto ondoso. Sezioni della spugna hanno inoltre evidenziato che tali gasteropodi si limitavano ad infestare la superficie.

***Ersilia mediterranea* (Fig. 3)**

Specie citata di rado e quasi esclusivamente per il bacino meridionale del Mediterraneo (Sicilia, Tunisia, Algeria, Golfo di Gabes). Negli ultimi anni, però, l'area di distribuzione tende a spostarsi sempre più a Nord come viene dimostrato da diverse segnalazioni.

Pirozzi identifica questo piccolo Lacunide nel detrito del Golfo di Napoli (Ghisotti, 1978).

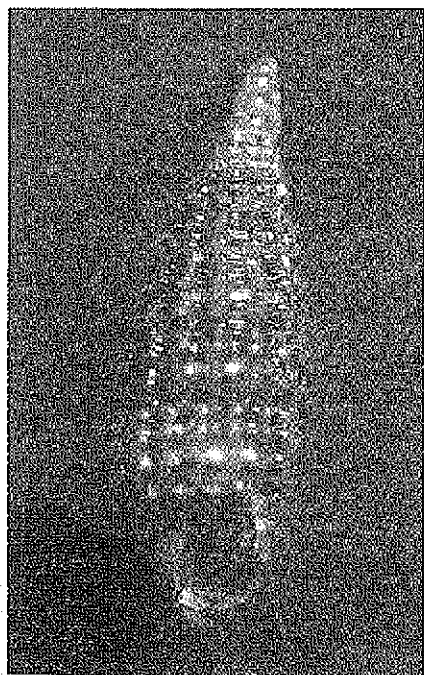


Fig. 2: *Cerithiopsis nana* Jeffreys, 1867.  
Altezza: mm 2,4.  
Sl. 2: *Cerithiopsis nana* Jeffreys, 1867.  
Višina: 2,4 mm.

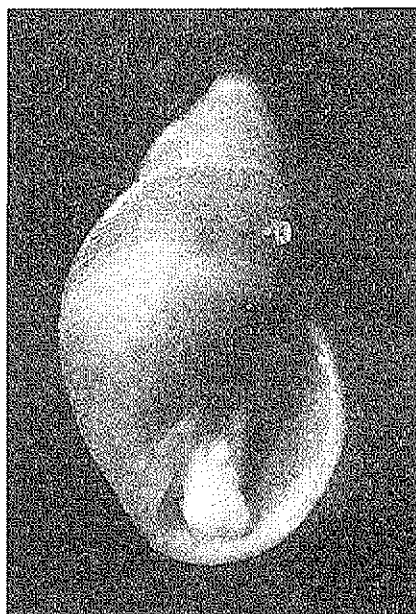


Fig. 3: *Ersilia mediterranea* (Monterosato, 1869).  
Altezza: mm 1,3.  
Sl. 3: *Ersilia mediterranea* (Monterosato, 1869).  
Višina: 1,3 mm.

Successivamente vengono raccolti un esemplare a Capo Passero (Siracusa), uno presso l'isola di Capraia (Livorno) a 80 metri di profondità ed un altro nella baia di Paraggi (Genova): quest'ultimo, inoltre, si presenta in ottime condizioni di freschezza e con residui di parti molli (Cecalupo, 1981).

Per quel che concerne l'Adriatico Settentrionale *Ersilia mediterranea* viene rinvenuta per la prima volta a Veruda (Pola) (Babbi & Rinaldi, 1981); nel 1983 viene citata per l'Isola d'Elba (Mietto & Quaggiotto, 1983) e Hoenselaar & Hoenselaar, nel 1989, pubblicano nel Bollettino della S.I.M. una cartina che illustra il bacino del Mediterraneo con tutti i ritrovamenti di questa piccola specie.

In aggiunta a tali dati, vi è la segnalazione degli AA. dell'esemplare raccolto a 10 metri circa di profondità a Cervera, presso Parenzo, nel luglio del 1997, su una piccola prateria di *Cymodocea* in un canalone creato dalle correnti di fondo.

#### *Thracia distorta* (Fig. 4)

Specie che vive nelle fenditure delle rocce, o nei fori praticati da molluschi perforanti. La morfologia delle valve si presenta molto variabile poiché *Thracia distorta* si adatta alla dimora scelta; questa peculiarità ha spesso reso difficile la sua determinazione e per tale motivo diversi studiosi sono stati tratti in inganno (Barsotti, 1970).

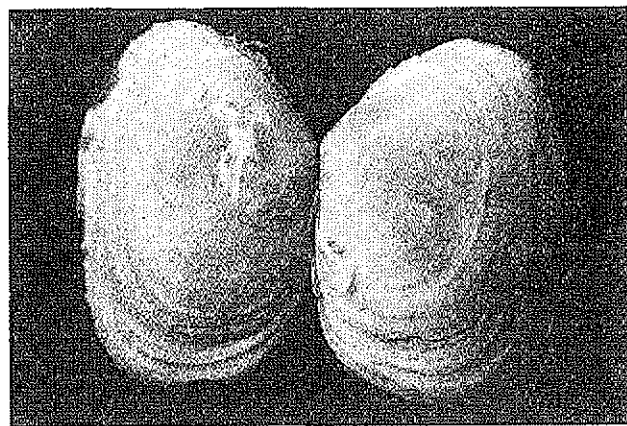


Fig. 4: *Thracia distorta* (Montagu, 1803).

Lunghezza: mm 5,8.

Fig. 4: *Thracia distorta* (Montagu, 1803).

Dolžina: 5,8 mm.

#### DISCUSSIONE

Lungo il tratto di costa studiato dal 1995 al 1998 a livello di malacofauna, sono state individuate 395 specie di molluschi: 8 Polyplacophora (2%), 272 Gastropoda (quasi il 69%), 107 Bivalvia (27%), 4 Scaphopoda (1%) e 4 Cephalopoda (1%).

Il numero delle specie rinvenute viventi è di 228 e rispetto al totale dei taxa raccolti, si aggira attorno al 58%; ciò chiaramente è significativo poiché testimonia l'importanza dell'azione di accumulo del materiale sulla riva ad opera delle mareggiate, soprattutto nei mesi autunno-invernali: essa infatti permette una miglior conoscenza degli organismi che provengono anche dalle biocenosi del circolitorale (vedi lista molluschi) poste al largo in acque più profonde.

Gli Opisthobranchia segnalati sono caratteristici del mesolitorale e dell'infralitorale anche se in alcuni casi (*Bulla striata*, *Scaphander lignarius* e *Cavolinia tridentata*) sono stati raccolti nel detrito depositatosi nella biocenosi del Detritico Costiero.

Confrontando i dati malacologici pubblicati da Vato-va (1928) per le acque di Rovigno, non molto distante geograficamente da Cervera, risulta che l'Autore aveva identificato 339 specie (pari quasi all'86% di quelle citate in questo lavoro); ciò dimostra una notevole conoscenza dei molluschi già all'inizio del secolo.

Il gran numero di specie determinate, conferma l'attuale ricchezza dell'Alto Adriatico, peraltro già rilevata dagli stessi AA. nella pubblicazione del 1996 sul Golfo di Trieste in cui sono stati elencati 493 molluschi presenti provvisti di conchiglia (Vio & De Min, 1996).

La notevole biodiversità dell'area studiata, per quanto riguarda la malacofauna, appare chiara anche paragonando il numero di specie da noi osservate (395), con il totale di quelle viventi nel Mediterraneo: 2200 (compresi gli Aplacophora, recentemente scoperti); tale numero eleva la percentuale, per Cervera, a circa il 18%.

Volendo inoltre confrontare i dati raccolti da Passamonti *et al.* (1993) con quelli presentati, si evidenzia che sono abbastanza simili: infatti questi Autori indicano per Banjole, località posta vicino a Pola, la presenza di 213 specie di Molluschi, mentre a Cervera ne sono state rinvenute 395. Riteniamo comunque opportuno sottolineare che nell'insenatura di Banjole, dove il fondale degrada verso il mare aperto fino alla profondità di 40 metri ed è caratterizzato da sabbia pelitica frammista a rocce intervallate a praterie di zosteracee, la presenza di uno stabilimento per la lavorazione e la conservazione del pesce, lo scarso idrodinamismo e l'apporto di acque dolci, hanno sicuramente influito sia sul numero elevato di specie di Molluschi segnalati, sia sulla presenza di forme particolari quali *Conus ventricosus* Gmelin, 1791 (varietà di *C. mediterraneus*, dalla conchiglia più allungata che presenta alla base colori tendenti al rosso, rosa o arancio invece che grigio-verdi) (Poppe & Goto, 1991). Ciò non toglie che l'elevato indice di biodiversità del litorale di Cervera, sia maggiormente imputabile alla notevole varietà di biotopi che caratterizzano l'area e all'influenza antropica relativamente bassa. Tutt'ora, infatti, gli insediamenti urbani nella zona sono pochi, fatta eccezione per alcuni campeggi posti nelle vici-



nanze ed alcuni alberghi, edificati sottocorrente, nei pressi di Parenzo (Poreč).

Si può inoltre rilevare una differenza tra il numero di specie rinvenuto all'interno dell'insenatura di P.to Busola (328) e quello del litorale aperto verso l'Adriatico (totale 395 campionate): ciò è sicuramente imputabile al fatto che, essendo questo tratto di costa meno protetto dalle mareggiate è più frequente l'accumularsi sulla riva di specie viventi nelle biocenosi caratteristiche del circolitorale quali: il Detritico Costiero (D.C.), il Detritico Fangoso (D.E.), i Fanghi Terrigeni Costieri (V.T.C.) ed i Fondi Mobili Instabili (M.I.).

Purtroppo è facilmente ipotizzabile che l'incremento

del turismo previsto per i prossimi anni lungo la linea di costa, così come la costruzione di nuovi insediamenti alberghieri, potranno mutare ed influenzare negativamente le attuali condizioni ambientali, che rendono quest'area una tra le più favorevoli alla vita degli organismi bentonici dell'Adriatico Settentrionale.

#### RINGRAZIAMENTI

Desideriamo porgere un ringraziamento particolare al Sig. Duilio Di Massa per la lettura critica della parte sistematica ed al Sig. Willy de Mattia per la segnalazione di alcuni ritrovamenti malacologici.

## MEHKUŽCI MORSKEGA OBREŽJA PRI ČRVARJU (POREČ, ISTRA)

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#### POVZETEK

V obdobju med jesenjo 1995 in poletjem 1998 smo opravili vzorčevanja malakofavne obrežja pri Črvarju blizu Poreča. Natančneje smo določevali mehkužce v notranjosti zaliva Busuja, na dnu nasproti ležeče severne obale in vzdolž same obale zaliva. Določili smo skupno 395 vrst in te podatke primerjali z deli, ki izvirajo z začetka stoletja (Vatova, 1928), kot tudi z recentnimi (Passamonti et al., 1993; Vio & De Min, 1996). Kaže, da je biodiverziteteta zelo visoka glede na omejeno razširjenost raziskanega območja. Kljub temu obstaja možnost, da bosta razvoj turizma, predvsem gradnja kampov in privezov za čolne, kot tudi pozidava obale, negativno vplivala na to pestrost.

**Ključne besede:** mehkužci, seznam, Istria, severni Jadran

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## ECOLOGICAL CHARACTERISTICS OF SEAWATER INFLUENCED BY SEWAGE OUTFALL

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### ABSTRACT

*The impact of sewage discharge from the treatment plant at Piran through submarine outfalls approx. 3500 m off the coast was studied. During the years 1998-1999 six surveys of oceanographic parameters, nutrient concentrations and faecal coliforms were carried out at the central station between the two outfalls and at the reference station. The spreading of the sewage in the water column was detected through observing small vertical salinity oscillations ( $-0.1$  PSU) in layers of thickness less than 1 m, a few meters above the bottom. Sewage dispersal was confirmed by the presence of faecal coliforms. Their number increased (max. 1160/100 ml) in the layers with highest salinity oscillations. The ecological impact of submarine outfalls on the surrounding environment was highest in the case of ammonium, while for other nutrients the impact was almost negligible. This was confirmed by the relatively high correlation between faecal coliforms and ammonium ( $\rho=0.58$ ) in the near-field sewage plume, while there was no correlation ( $\rho=-0.05$ ) between these properties in the sewage at the treatment plant's outlet. The reference station proved to be unsuitable for comparison due to periodic bacterial contamination.*

**Key words:** sewage, submarine outfall, faecal bacteria, nutrients, coastal sea, Gulf of Trieste

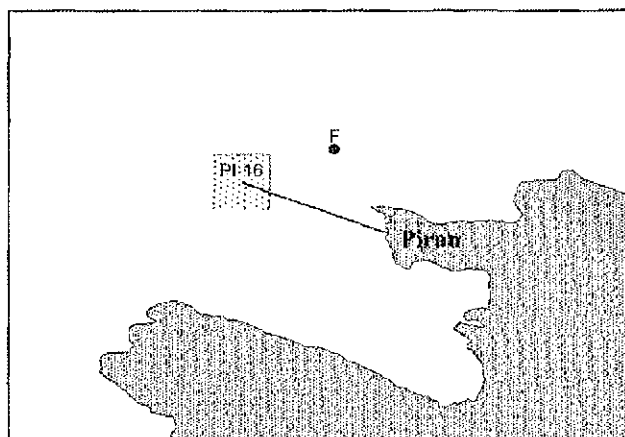
### INTRODUCTION

Near-shore marine areas are susceptible to many different land-based sources of pollution, among which direct, untreated wastewater discharge seems to be one of the main causes of increased eutrophication. This problem is even more evident in coastal areas where economically important activities, such as tourism and aquaculture, set high standards of seawater quality.

Many legislative acts have been successfully implemented in order to control the quality of the water body receiving municipal wastewaters and for the protection of human health. Slovenia started to monitor some pollution parameters within the frame of UNEP/MED-POL Program Phase II (Tušnik *et al.*, 1989) in 1983. Among several "hot spots", referred as land-based sources of pollution, sewage effluents at treatment plants were analysed from the very beginning.

In comparison to this well-developed net of pollution control on the land, the seawater in the vicinity of sewage discharges along the Slovenian coast did not gain such attention. Up to now, the majority of research work

concerning the effect of sewage dispersal in the marine environment was focused on the Piran sewage outfall (Gulf of Trieste, Adriatic Sea). The municipality of Piran, which is one of the most touristically developed Slovenian areas, solved the problem of sewage disposal in the late 70's by constructing a submarine sewage outfall 3450-m off the coast. Eleven years later, in 1987, another submarine outfall was constructed parallel to the old one at a horizontal distance of less than 200 m and 3250 m off the coast (Vukovič & Malačič, 1997). A mechanical treatment plant produces a sludge that is periodically removed from digestion tanks to an onshore dumping-ground, and an effluent, that is discharged by gravity through the outfalls into a depth of 21 m (Malej, 1980; Malačič, 1997). The old and new outfalls terminate with diffusers that are 108 m and 185 m long, respectively. They are placed 1 m above the bottom and are drilled alternately with 11 to 17 lateral holes on both sides of the pipes. Up to now these diffusers are the only ones in Slovenian waters. Average effluent flow is about 10360 m<sup>3</sup> per day and may increase during the season due to increased population (D. Kleva - Švigelj, *pers. comm.*).



**Fig. 1:** Location of the Piran submarine outfall, station grid and sampling stations in the southern part of the Gulf of Trieste. Sampling station PI-16 is located in the centre of the station grid.

**Sl. 1:** Lokacija piranskega podvodnega izpusta, mreže postaj in vzorčevalnih postaj v južnem delu Tržaškega zaliva. Postaja PI-16 leži v sredini mreže postaj.

Early studies comprised an overview of environmental conditions in the water column and at the sea floor before (1974/75) and after (1978/79) the construction of the first submarine outfall (Avčin *et al.*, 1978; Malej, 1980; Faganeli, 1982). The authors reported a minimal effect of the outfall upon the surrounding marine ecosystem, suggesting a very rapid dispersal of the effluent and thus the high effectiveness of the Piran treatment plant. No studies were done after the construction of the second outfall until recently.

In the last three years an extensive project has been undertaken in order to analyse the dispersion of the sewage plume from the Piran submarine outfall (Malačič, 1997, 1998; Vukovič & Malačič, 1997). The dynamics of sewage plume dispersion is controlled by stratification, shear currents, turbulence and the Coriolis force. Nutrients and faecal bacteria were occasionally monitored along with oceanographic parameters at the central station located between the two diffusers.

The purpose of this paper is to estimate the extent of sewage pollution in the water column based upon ecological parameters, and to extract the most representative parameters (*i.e.* indicators) of such pollution. Furthermore, we'll try to compare these new data with the data collected 20 years ago in order to assess possible deterioration of the marine environment and the effectiveness of the sampling strategy designed for such studies.

## MATERIALS AND METHODS

### Sampling strategy and field survey

Sampling was carried out at station PI-16 which is located between the submarine outfalls of Piran and at station F (Fig. 1) which is defined as the reference station. The central station PI-16 was chosen from a grid of 31 stations (Malačič, 1999a). During the years 1996-1998 several oceanographic surveys of the water column were undertaken. However, only four samplings from 1998 are presented in this paper. Biological and chemical parameters were sampled in addition to the CTD casts (conductivity, temperature, depth). An additional two samplings were performed in 1999. Surveys, labelled from 1 to 6, correspond to the following days: 2 April 1998 (1), 18 June 1998 (2), 31 August 1998 (3), 12 October 1998 (4), 24 May 1999 (5), and 21 July 1999 (6). Samplings were performed in calm weather and during low tidal currents - the tidal range of sea-surface elevation (peak-to-peak) was less than 0.6 m in the port of Koper.

The bottom at stations PI-16 and F is 21 m deep. The number and position of sampling depths varied from one sampling to another, and were defined each time separately with regard to the vertical salinity profile of station PI-16. The spreading of the sewage plume was detected from slightly lower salinity (for about 0.1 PSU) in thin layers within the water column. The number of sampling depths varied from 9 to 14, while the sampling depth interval was smaller than 2 m in the layers with slightly lower salinity. The reference station F was sampled only at a few depths, the number of which did not exceed five - the number of standard oceanographic depths (0.5, 5, 10, 15 m and just above the bottom). The exception was Survey 1 when sampling depths at station F corresponded to those at station PI-16.

Information about the input load was gained from the bacteria and nutrient analysis of sewage samples that were collected at the outflow of the treatment plant before each survey. The samples were collected about three to four hours before the sampling at station PI-16. It takes about this amount of time for the sewage to reach the sea (station PI-16).

On the basis of several oceanographic surveys of the water column near the sewage plume during different stratified conditions, a station grid was designed (Malačič, 1997). The grid with a diameter of approx.

900-m covers 31 stations around both outfalls and enables a fast dynamic survey (within one hour) of the plume extent. At grid stations vertical profiles of temperature, salinity, oxygen and fluorescence were obtained using the fine-scale multiparameter CTD probe, designed at the Centre for Water Research, University of Western Australia. The vertical resolution of the probe is of about 2.5 cm for a conventional drop speed of about 1 m/s.

### Analyses

**Nutrients.** Concentrations of nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ), ammonium ( $\text{NH}_4^+$ ), phosphate ( $\text{PO}_4^{3-}$ ) and silicate ( $\text{SiO}_4^{4-}$ ) were measured in unfiltered seawater and filtered sewage samples using standard colorimetric procedures (Grasshoff, 1983). Sewage samples were filtered through glass fibre filters (Whatman GF/F). Total nitrogen (N-tot) and total phosphorus (P-tot) were analysed in unfiltered samples. Inorganic nitrogen ( $\Sigma\text{N}_{\text{in}}$ ) was calculated as  $\text{NH}_4^+ + \text{NO}_3^- + \text{NO}_2^-$ .

**Faecal coliform bacteria.** The number of faecal coliforms was determined following the recommendations of UNEP/WHO (1994). Water samples were filtered through the 0.45  $\mu\text{m}$  pore-size Millipore filters and incubated on m-FC agar medium at  $44.5 \pm 0.2^\circ\text{C}$  for 24 hours.

**Statistical analyses.** Data from nutrient concentrations and faecal bacteria counts measured in the sewage at the outlet of the treatment plant and at the station PI-16 were statistically elaborated. Cross-correlation of standardised data was used to calculate correlation coefficients ( $\rho$ ) in order to examine the linear relationship

between properties (i.e. nutrients and faecal bacteria). Data were standardised using the following equation:

$$(\langle X \rangle - X_i) / \text{SD}$$

where  $X_i$  represents measured value,  $\langle X \rangle$  mean value and SD is the standard deviation of the specific parameter.

## RESULTS

### Sewage composition

Nutrient analyses and bacterial counts were performed on sewage effluent that was treated mechanically (Tab. 1). Almost all inorganic nitrogen was present as ammonium. Concentrations of ammonium, nitrite and nitrate varied substantially: from below the detection limit up to  $243 \mu\text{mol l}^{-1}$  in the case of nitrate. Except for samples collected on 12 October 1998 and 21 July 1999 the inorganic nitrogen (51-98% of total nitrogen) prevailed over organic forms.

More than 50% of total phosphorus was in the form of phosphate ( $\text{PO}_4^{3-}$ ), while other forms that are normally present in sewage, e.g. polyphosphate and organic phosphate, were not analytically separated. The highest concentrations of ammonium, phosphate, total nitrogen and phosphorus were measured during the summer months (31 August 1998 and 21 July 1999), while in the case of nitrate and nitrite it was just the opposite: during the summer they were at their minimum. Average count of faecal bacteria was around  $7.3 \times 10^6 / 100 \text{ ml}$  with a standard deviation of  $2.7 \times 10^6$ .

**Tab. 1: Composition of sewage water at the outflow of the Piran treatment plant: concentrations of nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ), ammonium ( $\text{NH}_4^+$ ), inorganic nitrogen ( $\Sigma\text{N}_{\text{in}}$ ), phosphate ( $\text{PO}_4^{3-}$ ), silicate ( $\text{SiO}_4^{4-}$ ), total nitrogen (N-tot) and phosphorus (P-tot) and number of faecal coliform bacteria (FC). Mean values of the parameters ( $\langle X \rangle$ ) and standard deviations (SD) are shown.**

**Tab. 1: Sestava odpadne vode na iztoku iz piranske čistilne naprave: koncentracije nitrata ( $\text{NO}_3^-$ ), nitrita ( $\text{NO}_2^-$ ), amonija ( $\text{NH}_4^+$ ), anorganskega dušika ( $\Sigma\text{N}_{\text{in}}$ ), fosfata ( $\text{PO}_4^{3-}$ ), silikata ( $\text{SiO}_4^{4-}$ ), celotnega dušika (N-tot) in fosforja (P-tot) ter število fekalnih koliformnih bakterij (FC). Podane so srednje vrednosti ( $\langle X \rangle$ ) in standardne deviacije (SD) merjenih parametrov.**

| date                | $\text{NO}_3^-$<br>( $\mu\text{mol l}^{-1}$ ) | $\text{NO}_2^-$<br>( $\mu\text{mol l}^{-1}$ ) | $\text{NH}_4^+$<br>( $\mu\text{mol l}^{-1}$ ) | $\Sigma\text{N}_{\text{in}}$<br>( $\mu\text{mol l}^{-1}$ ) | $\text{PO}_4^{3-}$<br>( $\mu\text{mol l}^{-1}$ ) | $\text{SiO}_4^{4-}$<br>( $\mu\text{mol l}^{-1}$ ) | N-tot<br>( $\mu\text{mol l}^{-1}$ ) | P-tot<br>( $\mu\text{mol l}^{-1}$ ) | FC<br>(No./100 ml) |
|---------------------|---|---|---|--|--|---|-------------------------------------|-------------------------------------|--------------------|
| 02/04/98            | 17.96   | 3.40  | 825.93  | 847.29   | 38.75  | 139.44  | 1651.17                             | 62.69                               | 3.90E+06           |
| 18/06/98            | 43.16   | 16.76   | 841.87  | 901.79   | 40.36  | 249.16  | 924.41                              | 61.48                               | 1.03E+07           |
| 31/08/98            | <0.01   | 0.04  | 1916.30                                       | 1916.34  | 46.71  | 388.27  | 1998.59                             | 109.69                              | 4.48E+06           |
| 12/10/98            | 20.92   | 14.32   | 299.30  | 334.54   | 24.16  | 201.60  | 920.50                              | 37.29                               | 8.00E+06           |
| 24/05/99            | 242.51  | 6.32  | 952.72  | 1201.55  | 58.22  | 220.43  | 1895.30                             | 90.18                               | 7.00E+06           |
| 21/07/99            | 3.04  | 0.07  | 1836.60                                       | 1839.71  | 102.28   | 262.28  | 5275.80                             | 115.97                              | 1.02E+07           |
| $\langle X \rangle$ | 54.60   | 6.82  | 1112.12                                       | 1173.54  | 51.75  | 243.53  | 2111.05                             | 79.55                               | 7.26E+06           |
| SD                  | 93.33   | 7.19  | 634.44  | 613.27   | 27.13  | 830.02  | 1619.34                             | 30.80                               | 2.68E+06           |

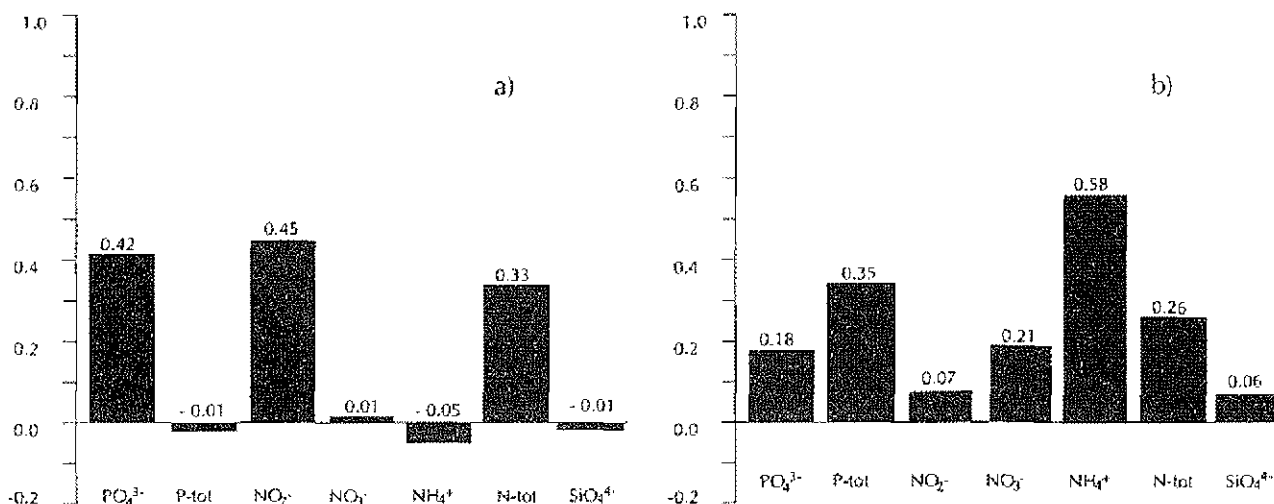


Fig. 2: Coefficients of cross-correlation analyses between faecal bacteria and nutrients.

a) data from the sewage at the outlet of the treatment plant  
 b) data from station PI-16

Sl. 2: Koefficienti korelacijske analize med fekalnimi bakterijami in hranilnimi snovmi.

a) podatki iz odpadne vode na iztoku iz čistilne naprave  
 b) podatki s postaje PI-16

Tab. 2: Coefficients of cross-correlation analyses performed on nutrient concentrations and faecal bacteria counts, which were measured in the sewage at the outlet of the Piran treatment plant (N = 6).

Tab. 2: Korelacijski koeficienti, izračunani za koncentracije hranilnih snovi in števila koliformnih bakterij (N = 6). Analize so bile opravljene v odpadni vodi na iztoku iz piranske čistilne naprave.

|                                | PO <sub>4</sub> <sup>3-</sup> | P-tot | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | NH <sub>4</sub> <sup>+</sup> | N-tot | SiO <sub>4</sub> <sup>4-</sup> | FC    |
|--------------------------------|-------------------------------|-------|------------------------------|------------------------------|------------------------------|-------|--------------------------------|-------|
| PO <sub>4</sub> <sup>3-</sup>  | 1                             | 0.80  | -0.60                        | 0.03                         | 0.71                         | 0.96  | 0.22                           | 0.42  |
| P-tot                          | 0.80                          | 1     | -0.81                        | 0.05                         | 0.95                         | 0.76  | 0.64                           | -0.01 |
| NO <sub>2</sub> <sup>-</sup>   | -0.60                         | -0.81 | 1                            | 0.11                         | -0.79                        | -0.68 | -0.33                          | 0.45  |
| NO <sub>3</sub> <sup>-</sup>   | 0.03                          | 0.05  | 0.11                         | 1                            | -0.24                        | -0.17 | -0.21                          | 0.01  |
| NH <sub>4</sub> <sup>+</sup>   | 0.71                          | 0.95  | -0.79                        | -0.24                        | 1                            | 0.71  | 0.74                           | -0.05 |
| N-tot                          | 0.96                          | 0.76  | -0.68                        | -0.17                        | 0.71                         | 1     | 0.21                           | 0.33  |
| SiO <sub>4</sub> <sup>4-</sup> | 0.22                          | 0.64  | -0.33                        | -0.21                        | 0.74                         | 0.21  | 1                              | -0.01 |
| FC                             | 0.42                          | -0.01 | 0.45                         | 0.01                         | -0.05                        | 0.33  | -0.01                          | 1     |

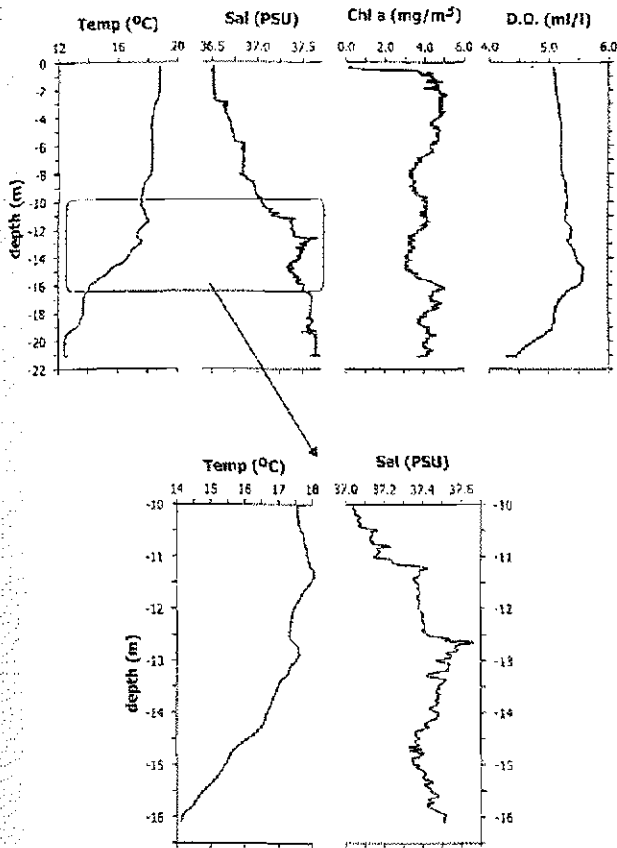
Cross-correlation analyses (Tab. 2) of nutrient concentrations and faecal bacteria in sewage show variable relationships among parameters. Some nutrients are highly correlated among each other (e.g. PO<sub>4</sub><sup>3-</sup>, P-tot, NH<sub>4</sub><sup>+</sup>, and N-tot), while faecal bacteria are only slightly correlated to phosphate and nitrite (Fig. 2a). There is no meaningful correlation between the bacteria and ammonium in the sewage.

**Vertical structure of the water column**

CTD casts were performed at every survey and sampling depths at station PI-16 were determined using the salinity vertical profile. In this work only one vertical profile of temperature, salinity, fluorescence and dissolved oxygen will be presented as an example (24 May 1999) of the fine vertical structure of the water column

that is affected by the sewage plume (Fig. 3). Warming of the atmosphere in late spring contributed to the rise of seawater temperature in the upper layers. Consequently, a weak stratification of the water column with a thermocline at approx. 12 m was re-established, separating the upper warmer layers (17.0-18.8°C) from the colder bottom ones (12.4-13.4°C). Salinity gradually increased with depth from the value at the surface (36.27 PSU) towards the value at the depth of the thermocline (37.04 PSU). In the layer between 11 and 16 m slight oscillations of salinity ranged from 0.03 to 0.12 PSU. They indicate an intrusion of less saline water presumably originating from the outfalls. Below 16 m depth the salinity increased again and reached the maximum (37.69 PSU) at the bottom. The fluorescence peak and highest oxygen concentration were detected at a depth of around 16 m. The salinity vertical profile was crucial for





**Fig. 3:** Temperature, salinity (Sal), in situ fluorescence (Chl a) and dissolved oxygen (D.O.) vertical profiles recorded on May 24, 1999 using CTD fine-scale probe. A detail of vertical profiles of temperature and salinity between 10 and 16 m depth is shown in the lower figure.

**Sl. 3:** Vertikalni profili temperature, slanosti (Sal), in situ fluorescence (Chl a) in raztopljenega kisika (D.O.), posneti s CTD sondo 24. maja 1999. Na spodnji sliki je prikazan izsek vertikalnih profilov temperature in slanosti na globini 10 do 16 m.

determination of 12 sampling depths. Between the depth range 11.5-16.5 m the samples were collected at depths with an interval smaller than 1 m.

### Water quality of the recipient

Nutrient concentrations and the sanitary quality of the seawater were measured in the near-field of the sewage plume (station PI-16), as well as at the reference station (station F), in order to examine the impact of sewage on the surrounding media. Fine-scale vertical distributions of chemical and microbiological param-

eters during six surveys at station PI-16 are shown in figures 4a and 4b.

Faecal coliforms are the fundamental indicators of sewage pollution. Therefore, we first followed the distribution of bacteria in the water column. Secondly, we compared nutrients to bacterial distribution in order to determine the most representative nutrient(s) of sewage dispersion. The number and vertical distribution of faecal coliforms differed substantially among the six surveys (Fig. 4a, upper panel). On 18 June 1998 we observed no sewage at station PI-16, while on other occasions the number of bacteria varied from less than 1 to 1160/100 ml. A peak value of 1160 counts/100 ml was counted on 2 April 1998 at depth of 12 m, with the second highest 890 counts/100 ml at depth of 14 m on 24 May 1999. Low values, apart from the situation of zero counts on 18 June 1998, were counted during late summer (31 August 1998). Then, the highest count of 215/100 ml was reached at the bottom.

The vertical distribution of faecal coliforms also varied substantially. During spring surveys (2 April 1998 and 24 May 1999) the bacteria were present only in a narrow layer of a thickness of 3 m between depths of 11 and 14 m. An approx. 15-fold increase was detected at depths of 12 m and 14 m with respect to counts at other depths. During other periods faecal coliforms were more evenly distributed throughout the water column. Bacteria were found in a thicker layer between 7 and 13 m, with peak values at the bottom (31 August 1998) and at depths between 11 and 16 m (12 October 1998 and 21 July 1999).

With a few exceptions vertical profiles of ammonium followed faecal vertical distributions (Fig. 4a, upper panel). Peaks of ammonium (4.08 - 7.33  $\mu\text{mol l}^{-1}$ ) were measured at the same depths as bacterial maximums, and also at the bottom (3.23  $\mu\text{mol l}^{-1}$ ). Concentrations of other nitrogen forms, especially nitrate, were generally higher in the upper layers of the water column (1.83 - 6.01  $\mu\text{mol l}^{-1}$ ) and again at the bottom (7.72  $\mu\text{mol l}^{-1}$ ; Fig. 4b, lower panel). Phosphate and total phosphorus (Fig. 4b, upper panel) showed a similar vertical pattern. Extremely high phosphate concentrations were measured on 31 August 1998 at the surface (0.30  $\mu\text{mol l}^{-1}$ ), at the bottom (0.92  $\mu\text{mol l}^{-1}$ ) and at 15 m depth (0.41  $\mu\text{mol l}^{-1}$ ). In other cases the concentrations of phosphate were below 0.10  $\mu\text{mol l}^{-1}$ . Increased phosphate and total phosphorus values were only occasionally observed in the layers where faecal coliforms were present. Silicate concentrations varied from 1.85 to 34.72  $\mu\text{mol l}^{-1}$  (Fig. 4a, bottom panel). Similarly to nitrate, the highest values of silicate concentrations were generally measured in the bottom layers (except for 2 April and 31 August 1998).

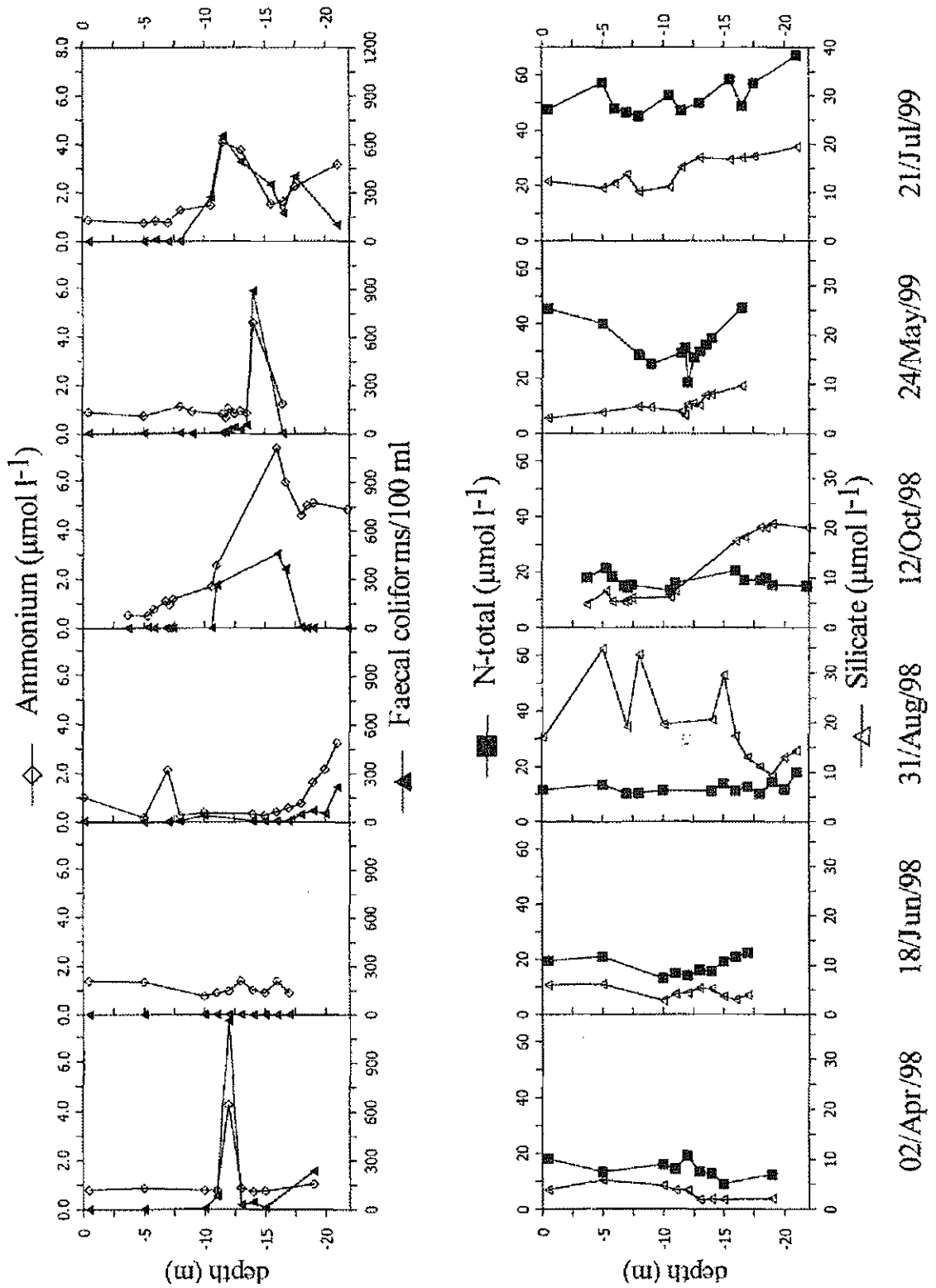


Fig. 4a: Vertical distribution of faecal coliform bacteria, ammonium, total nitrogen (N-total) and silicate at station PI-16 during six surveys during the years 1998-1999.

Sl. 4a: Vertikalna porazdelitev fekalnih koliformnih bakterij, amonija, celotnega dušika (N-total) in silikata na postaji PI-16 tekom šestih vzorčevanj med leti 1998-1999.

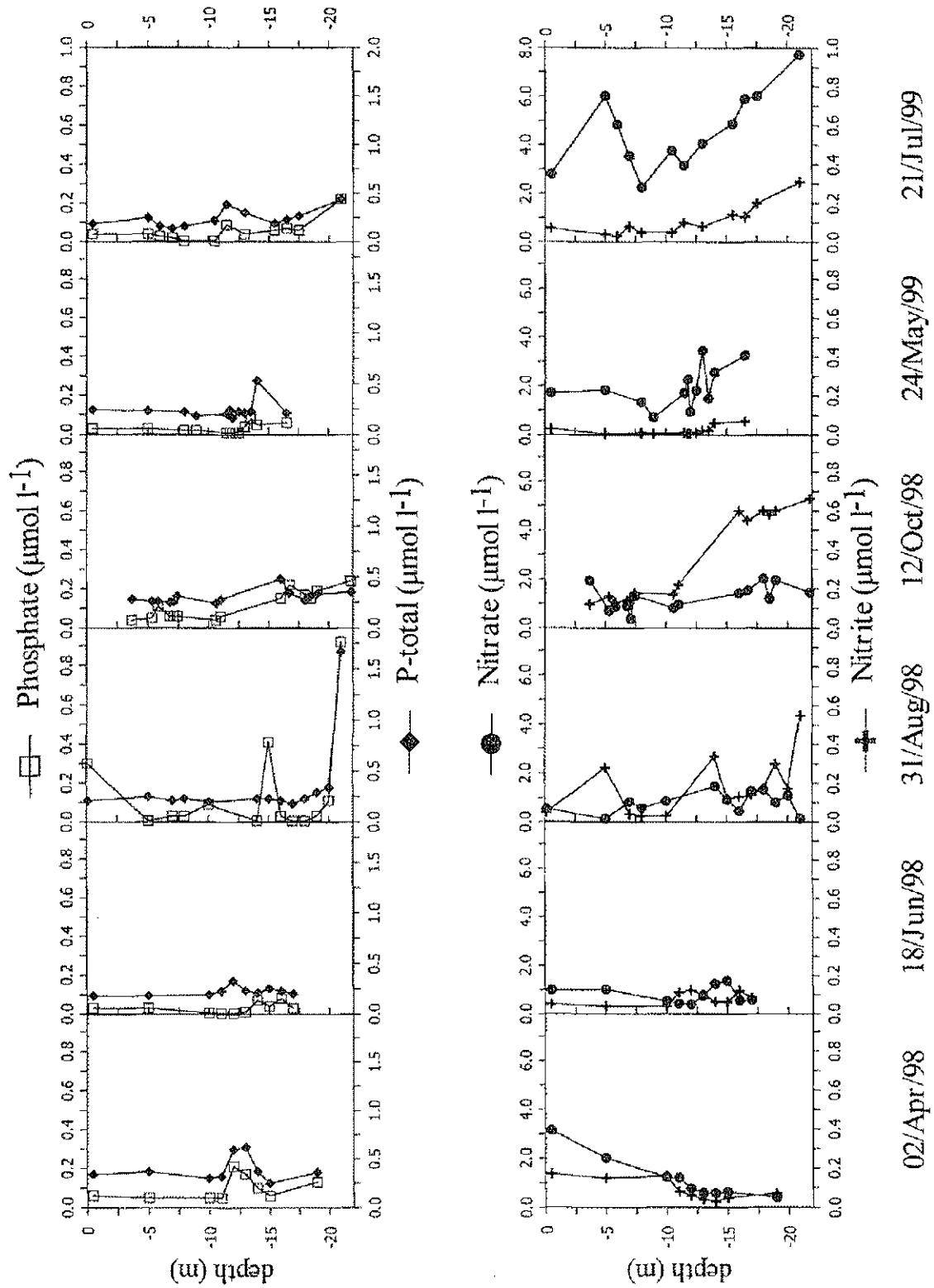


Fig. 4b: Vertical distribution of phosphate, total phosphorus (P-total), nitrate and nitrite at station PI-16 during six surveys during the years 1998-1999.

Sl. 4b: Vertikalna porazdelitev fosfata, celotnega fosforja (P-total), nitrata in nitrita na postaji PI-16 tekom šestih vzorčevanj med leti 1998-1999.

**Tab. 3: Coefficients of cross-correlation analyses performed on nutrient concentrations and faecal bacteria counts, which were measured in the seawater at station PI-16 (N = 70).**

**Tab. 3: Korelacijski koeficienti, izračunani za koncentracije hranilnih snovi in števila koliformnih bakterij (N = 70). Analize so bile opravljene v morski vodi na postaji PI-16.**

|                                | PO <sub>4</sub> <sup>3-</sup> | P-tot | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | NH <sub>4</sub> <sup>+</sup> | N-tot | SiO <sub>4</sub> <sup>4-</sup> | FC   |
|--------------------------------|-------------------------------|-------|------------------------------|------------------------------|------------------------------|-------|--------------------------------|------|
| PO <sub>4</sub> <sup>3-</sup>  | 1                             | 0.82  | 0.49                         | -0.10                        | 0.37                         | -0.12 | 0.27                           | 0.18 |
| P-tot                          | 0.82                          | 1     | 0.40                         | -0.11                        | 0.37                         | -0.09 | 0.02                           | 0.35 |
| NO <sub>2</sub> <sup>-</sup>   | 0.49                          | 0.40  | 1                            | -0.02                        | 0.72                         | -0.19 | 0.47                           | 0.07 |
| NO <sub>3</sub> <sup>-</sup>   | -0.10                         | -0.11 | -0.02                        | 1                            | 0.14                         | 0.87  | 0.19                           | 0.21 |
| NH <sub>4</sub> <sup>+</sup>   | 0.37                          | 0.37  | 0.72                         | 0.14                         | 1                            | 0.09  | 0.29                           | 0.58 |
| N-tot                          | -0.12                         | -0.09 | -0.19                        | 0.87                         | 0.09                         | 1     | 0.07                           | 0.26 |
| SiO <sub>4</sub> <sup>4-</sup> | 0.27                          | 0.02  | 0.47                         | 0.19                         | 0.29                         | 0.07  | 1                              | 0.06 |
| FC                             | 0.18                          | 0.35  | 0.07                         | 0.21                         | 0.58                         | 0.26  | 0.06                           | 1    |

Nutrients and faecal bacteria measured at station PI-16 were statistically elaborated in a way similar to that for the sewage effluent. Data from all six surveys collected at all depths were cross-correlated (Tab. 3). The strongest relationships were observed between PO<sub>4</sub><sup>3-</sup> and P-tot, and NO<sub>3</sub><sup>-</sup> and N-tot ( $\rho = 0.82$  and  $0.87$ , respectively). However, the impact of sewage discharge on the recipient is revealed with the correlation between faecal bacteria, indicators of such pollution, and nutrients (Fig. 2b). The highest correlation coefficient between bacteria and nutrients was calculated in the case of ammonium ( $\rho = 0.58$ ). A relatively low correlation coefficient was observed for total phosphorus ( $\rho = 0.35$ ). In all other cases (faecal coliforms vs. nitrite, nitrate, total nitrogen, phosphate and silicate) there was no meaningful correlation, indicating no effect of sewage input on these nutrient forms.

#### Nutrients and sanitary quality at the reference station

Station F was chosen as a reference station because we expected no impact of sewage pollution at that station. We therefore compared the nutrient data from both stations (PI-16 and F).

Faecal coliforms were absent at the station F (Fig. 5) during four samplings in 1998 except for the slight increase in the bottom layer on 31 August 1998. On the contrary, they were found on both 1999 samplings at depths below 10 m with relatively high numbers on 24 May 1999 (450 and 165 counts/100 ml). Concentrations of all nutrients were in a range similar to the range of nutrients measured at station PI-16. On average, nitrate and total nitrogen were higher at station F (2.30 and 36.51  $\mu\text{mol l}^{-1}$ , respectively) while all other mean values were higher at station PI-16. It should be stressed, however, that the number of sampling depths at station F was lower than the number of depths at station PI-16.

Moreover, half of the samplings at station F were taken only in subsurface or middle layers. A thorough comparison is therefore limited.

#### DISCUSSION

The sewage composition from the Piran treatment plant shows a high variability of parameters during six samplings (Tab. 1). High concentrations of nitrate and nitrite in the sewage were measured in spring, while during the summer period they were close to the detection limit. These forms of nitrogen are normally absent from fresh sewage as they are products of the biological oxidation processes within the treatment plant (Masters, 1998). Therefore, high oscillations of nitrite and nitrate in Piran sewage might be attributed to the different age of the sewage at the time of sampling. We have to consider also that the Piran sewerage system is of a combined type, meaning that during heavy rainfalls surface drainage waters coming from roads, roofs and paved areas are collected in the treatment plant. This leads to fluctuations in both the volume and concentration of sewage. It was shown in a previous work (Malej *et al.*, 1997) that the main nitrogen form in the rainwater that was collected at the local meteorological station was nitrate. A considerable fraction of nitrogen was bound in the organic form.

The concentration of ammonium could also, to some extent, be an indicator of the age of the sewage as this form of nitrogen is the final product of the decomposition processes of organic nitrogen and hydrolysis of urea (Masters, 1998). Higher concentrations of ammonium during the summer might also be attributed to the increased tourist population and not only to the age of the sewage. The same conclusion might be drawn about orthophosphate, total nitrogen and phosphorus. Faganelli (1982) already observed this in a previous work.

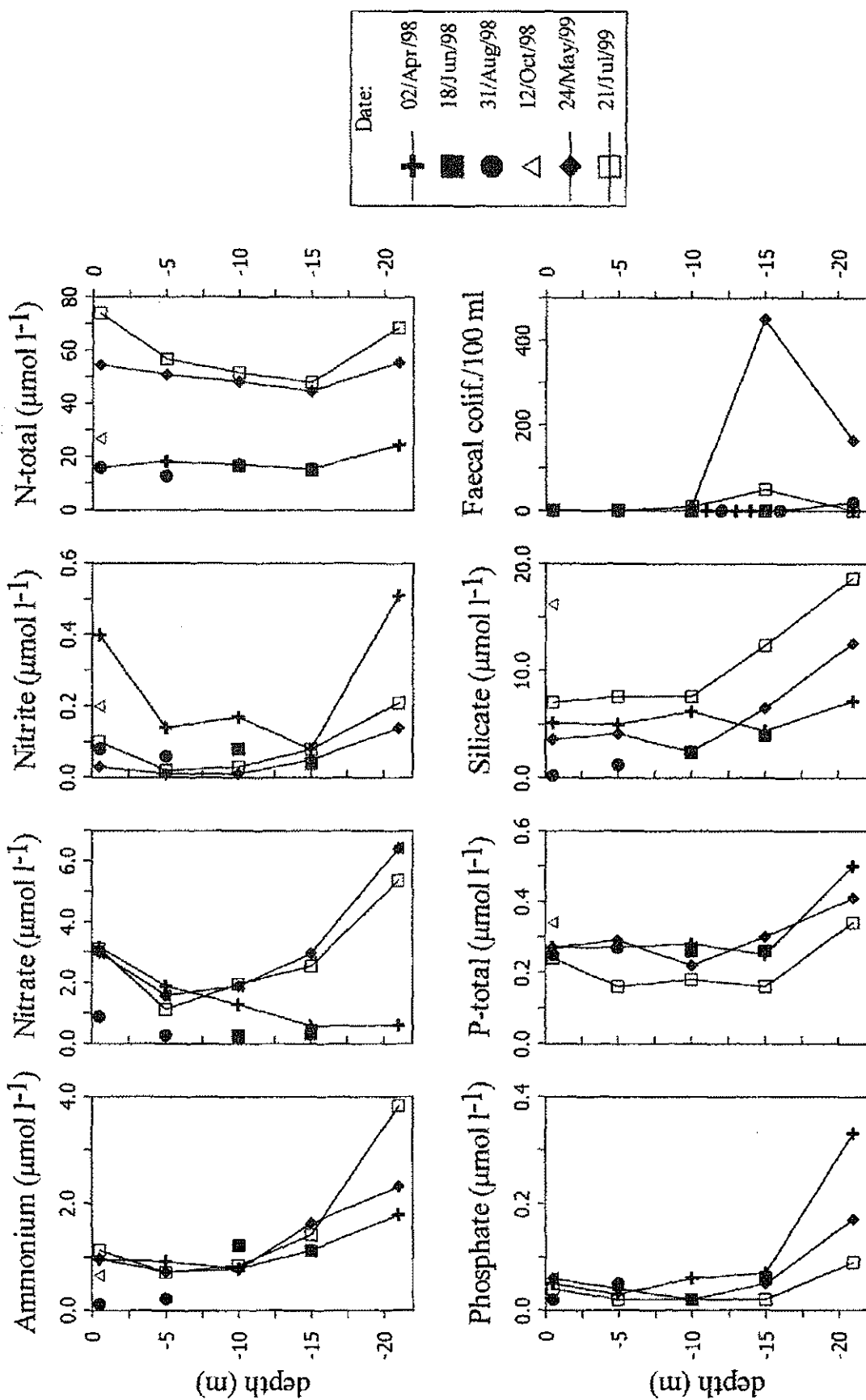


Fig. 5: Vertical distribution of nutrients and faecal coliform bacteria at reference station F during six surveys during the years 1998-1999.  
 Sl. 5: Vertikalna porazdelitev hranilnih snovi in fekalnih koliformnih bakterij na referenčni postaji F tekom šestih vzorčevanj med leti 1989-1999.

After mechanical treatment the sewage is gravitationally released to the sea through the two outfalls. Oceanographic properties of the recipient at station PI-16 on 24 May 1999 were shown as an example. At that time the less saline water, presumably originating from the two diffusers, was retained below the thermocline at a depth of 12 m. The sewage plume was identified by small salinity oscillations in the range of 0.03 to 0.12 PSU in thin layers of a thickness of less than 1 m at depths between 13 and 15 m. The sampling strategy was arranged in such a way that the sewage plume was detected as much as possible through frequent samplings that were separated along the vertical by less than 1 m. On 24 May 1999 frequent sampling was performed in depths between 11.5 and 16.5 m.

A detailed three-year study of the oceanographic properties around the submarine outfall confirms that within the turbulent wastewater field the fluctuations of temperature are in general of the order of 0.1°C, and of salinity less than 0.1 PSU (Malačič, 1999a). During periods of stratified water column the sewage plume generally lies at depths between 13 and 18 m - a few meters above the bottom, while during the homogeneous water column (winter), sewage can emerge at the surface (Vuković & Malačič, 1997; Malačič, 1999b). The sewage plume spreads horizontally in thin lenses of a thickness of less than 1 m in windless, stratified conditions (Malačič, 1999a). Small vertical variations of temperature and salinity that characterise these lenses indicate very fast dilution of sewage close above both diffusers. The study also showed that without seasonally-oriented measurements (*i.e.* CTD casts) it is very difficult to separate the influences of ambient conditions (*e.g.* currents, winds, tide) on the spreading and rising of sewage. One possibility, although expensive, would be to use dye tracers (*e.g.* rhodamin) (Proni *et al.*, 1994; Adams *et al.*, 1998; Yilmaz *et al.*, 1998).

The spreading of a sewage plume was confirmed by measurements of faecal coliforms. Faecal coliform bacteria such as *Escherichia coli* are traditionally used as indicators of sewage contamination because they appear to be specific to sewage pollution. They are present in large numbers, relatively easy to quantify (Nichols *et al.*, 1993), and are taken as a sign of potential pathogen presence. Domestic sewage discharged in coastal waters contains an unhealthy mix of both harmless and infectious microorganisms, such as faecal streptococci (*Streptococcus faecalis*) and human pathogenic viruses, which are more resistant to environmental stress and thus survive longer in the marine environment (days-weeks). Recent studies indicate that, instead of faecal coliforms, sterol biomarkers could also be a suitable parameter to detect sewage (Mudge & Gwyn Lintern, 1999), especially when a historic measure of sewage contamination is required. The comparison between the measurements of 24 May 1999 (Fig. 4a, upper panel)

with the CTD cast (Fig. 3) showed that the occurrence and high number of faecal coliforms coincided with the layer of highest salinity oscillations along the vertical. Similar vertical distribution of salinity and bacteria was also observed during other months with the peak values of bacteria always below 10 m. The only exception was 18 June 1998 when no faecal coliforms were detected. Absence of bacteria was also observed during other surveys performed between 1996 and 1997 (Vuković & Malačič, 1997). Faecal coliforms have been found also in the upper layers (above 10 m), but only during the homogenous water column (Vuković & Malačič, 1997; *unpubl. data*). A possible explanation for the bacterial absence at station PI-16 observed on 18 June 1998 and reported previously by Vuković & Malačič (1997) can be attributed to the fact that the sampling was not performed exactly at station PI-16. At this station the sampling usually takes half an hour. Since anchoring is prohibited at that position the research vessel drifted away from station PI-16 approx. 400 m due to winds and surface currents. Besides ineffective sampling there are other plausible factors which may considerably reduce the survival rate of faecal bacteria in the marine environment - primarily solar radiation, as well as salinity, pH changes, the presence of toxic substances, predation and parasitism, lysis by bacteriophage, suboptimal water temperature, and nutrient deficiencies (Cheryl *et al.*, 1995; Šolić & Krstulović, 1992). The effect of another factor, the osmotic stress due to moving from fresh to saline waters, is even more intensified when the sampling is performed outside the near-field of the sewage plume (*i.e.* drifting of the vessel).

The highest number of faecal coliforms (from 215 to 1160/100 ml) is above the regulation limit for bathing waters set by the State Department for Public Health, which require less than 100 coliforms/100 ml (Official Gazette, 1988). The area around the Piran submarine outfall is not designed for bathing or aquaculture activity. On the contrary, no activity should be allowed in the zone around the diffusers. According to UNEP (1995) recommendations "... as a precaution against damage by anchors or fishing gear, submarine outfalls should be marked with clear buoys at the end at every bend of the unprotected part, fitted with clear signs prohibiting anchoring and fishing in a 200 m radius around it, and warning against swimming or wind-surfing in the vicinity." These high coliform numbers should be a major concern from the point of view of the treatment plant operation. Taking into account the number of faecal coliforms at the treatment plant outlet (Tab. 1) and in the sea, the abatement factor of the microbial load was between  $10^4$  and  $10^7$  in most cases (97%) which is beyond the range of UNEP recommendations for submarine outfalls (UNEP, 1995). Only in the two highest cases of bacterial contamination (890 and 1160/100 ml) the abatement factor was around  $10^3$



which is in agreement with UNEP recommendations (1995). This abatement factor is usually a combination of initial hydraulic dilution over a submarine pipe and of bacterial decay. UNEP (1995) recommends an outfall system that ends with a diffuser of appropriate length at a certain distance from sensitive areas (e.g. bathing areas). This recommendation is met for the outfall at Piran. However, it is planned that the submarine outfall will be combined with the chemical disinfection of sewage sludge to decrease bacterial abundance and nutrient load even more.

Bacterial numbers were correlated with nutrient concentrations, and nutrient measurements at both stations (station PI-16 and reference station F) were compared in order to detect other indicative parameter(s) of sewage pollution. Vertical distribution of analysed substances (Figs. 4a, 4b), and calculated correlation coefficients between them (Tab. 3, Fig. 2b) show that only ammonium could be an indicator of sewage dispersion ( $p = 0.58$ ). Interestingly, this relationship between ammonium and faecal bacteria cannot be detected in the sewage effluent (Tab. 2, Fig. 2a) where other nutrient species (phosphate and nitrite) are more linearly correlated to bacteria than ammonium, although this correlation is relatively weak. All other nutrient concentrations at the station PI-16 are comparable to the concentrations at the reference station (Fig. 5) and to concentrations that are generally measured in the southern part of the Gulf of Trieste (Vukovič *et al.*, 1997-1999). Thus, only a slight influence of sewage dispersal on the pelagic environment was detected. In the Gulf of Trieste maximal concentrations of ammonium are generally measured at the bottom (Vukovič *et al.*, 1997-1999). They result from degradation and sedimentation processes. In the water column above the submarine outfall the ammonium peak values (4.56-7.33  $\mu\text{mol l}^{-1}$ ) were up to two times

higher than those measured at the reference station (max. 3.83  $\mu\text{mol l}^{-1}$ ) and were found in the layers of highest bacterial contamination. Sometimes the peak was detected at the bottom. Concentrations and vertical distribution of remaining nutrients are most likely greatly influenced by other external inputs (e.g. rain water, river water; Malej *et al.*, 1995, 1997) and processes (biological uptake, bacterial degradation, sedimentation, entrapment at the bottom). This hypothesis is even more plausible when variable sewage composition and fast dilution at the diffuser's outlet is taken into account. Except for ammonium, and to a lesser extent for total phosphorus, station PI-16 reflects similar nutritional conditions as station F. Similar findings were described for more polluted areas than the Bay of Piran, with higher external nutrient loads (municipal wastewater, industry, rivers). A water quality study of Tampa Bay in Florida (Wang *et al.*, 1999) showed that external loading of ammonium comprised less than 1% of total ammonium flux and that major seasonal variations can be attributed to mineralisation of organic nitrogen (algal death and respiration) and to phytoplankton uptake.

In terms of bacterial contamination, station F was found unsuitable as a reference site. The distance between the two stations is 0.85 Nm. Historically, station F has a recognisable status as a reference station for the non-polluted, open-waters of the Gulf of Trieste (Fanuko, 1986). On both 1999 surveys faecal coliforms were found at this station, indicating the impact of sewage discharge on the environment, presumably due to specific oceanographic properties at that time. High bacterial numbers were counted again in November 1999 at depths between 8 and 10 m (*unpubl. data*). This fact necessitates simultaneous measurements of currents at different depths.

Tab. 4: Comparison of the mean nutrient concentrations measured 20 years ago (Faganeli, 1982), and mean nutrient concentrations from this work at the station above the submarine outfall at Piran.

Tab. 4: Primerjava srednjih vrednosti koncentracij hranilnih soli v površinskem in pridnenem sloju, izmerjenih pred 20 leti (Faganeli, 1982) in tistih, izmerjenih v tej študiji, na postaji v bližini piranskega podvodnega izpusta.

| Parameter<br>( $\mu\text{mol l}^{-1}$ ) | Surface layer   |           | Bottom layer    |           |
|---|-----------------|-----------|-----------------|-----------|
|   | Faganeli (1982) | this work | Faganeli (1982) | this work |
| $\text{NO}_2^-$                         | 0.23            | 0.08      | 0.29            | 0.33      |
| $\text{NO}_3^-$                         | 2.18            | 1.84      | 1.95            | 2.05      |
| $\text{NH}_4^+$                         | 2.18            | 0.92      | 2.97            | 2.62      |
| $\Sigma\text{N}_{\text{in}}$            | 4.59            | 2.84      | 5.41            | 5.00      |
| $\text{PO}_4^{3-}$                      | 0.18            | 0.08      | 0.16            | 0.31      |

Finally, a comparison was made between recent nutrient data and the data measured 20 years ago (Malej, 1980; Faganelli, 1982) when the treatment plant of Piran started to operate (Tab. 4). Concentrations measured only in the surface and bottom layers were considered for the comparison. Mean nutrient concentrations presented in this work are generally lower than those reported by Faganelli (1982), especially in the surface layer. Only in the case of phosphate in the bottom layer are mean concentrations of recent measurements higher than those measured two decades ago. These slight differences in nutrient concentrations within the last 20 years indicate no major deterioration of the pelagic environment, although a continuous monitoring of water column properties is missing for an affirmative conclusion in this direction (*i.e.* long-term studies). Prompt monitoring of the sediment is even more crucial - no information about the deterioration of the sediment over the last 20 years is available. To date only one survey of the bottom organisms in the vicinity of the sewage outfall has been performed since the treatment plant started its operation (Avčín *et al.*, 1978). The need for an overall survey of the sediment structure and benthic communities is even more profound if we consider the higher susceptibility of the sediment to pollution over time as compared to the pelagic environment (Gray *et al.*, 1990). The impact of sewage discharge on the sediment has to be considered also in view of its greater potential for faecal contamination. A recent study (Pommeuys *et al.*, 1992) has shown that sediments can accumulate a variety of microorganisms, such as faecal coliforms, faecal streptococci, *Clostridium perfringens* spores, and viruses. Sediments may contain 100 to 1000 times as many faecal indicator bacteria as the overlying water and may provide a favourable, nonstarvation environment for the bacteria (Cheryl *et al.*, 1995; Ashbolt *et al.*, 1993).

Comparison between recent and past studies of the impact of sewage discharge also brings up the shortcomings of sampling design, which in turn is reflected in the results. During her study Malej (1980) observed faecal coliforms only at the bottom of station PI-16, whereas at a depth of 10 m and at the surface no bacterial contamination was reported. It must be pointed out that in both studies (Malej, 1980; Faganelli, 1982) only the layers at the surface, at the bottom and at 10 m depth were sampled. Our study showed that the past sampling strategy was inadequate since much important information can be lost. All recent studies (Vukovič & Malačič,

1997; Malačič, 1999a, 1999b) also demonstrated the importance of a small-scale vertical sampling strategy in such an extremely variable environment, where the indicator parameters, and furthermore, undesirable eutrophication effects are difficult to follow.

## CONCLUSIONS

Our results showed a relatively high correlation between faecal bacteria and ammonium at the station above the submarine outfalls. Thus, in addition to faecal coliforms, ammonium can be identified as an indicator of the faecal pollution in the near-field sewage plume. Almost no correlation was observed between bacteria and other nutrients. Except for the ammonium no meaningful impact of the sewage discharge on the surrounding environment was observed when compared with nutrient concentrations at reference station F. Bacterial contamination was sometimes detected at station F, which was therefore found unsuitable as a reference site.

A small-scale vertical sampling scheme with unevenly distributed sampling depths proved to be a successful strategy for the detection of sewage spreading in the water column. Drawbacks of the survey are related to the long sampling time and technical/human limitations (not enough sampling depths in the upper water column, lack of measurements of currents). The sampling scheme was based on small salinity fluctuations in the range of 0.1 PSU along the vertical. These vertical oscillations indicate thin lenses of sewage.

A comparison between nutrient concentrations, measured in the vicinity of the outfalls in this study and concentrations measured 20 years ago, did not demonstrate a deterioration of the pelagic environment. However, continuous sewage discharge over the last two decades has probably affected the sediment - its chemical structure and bottom organisms. The lack of these data strongly necessitates further studies of the sediment.

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## EKOLOŠKE ZNAČILNOSTI OBALNEGA MORJA V BLIŽINI PODVODNEGA KANALIZACIJSKEGA IZPUSTA

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### POVZETEK

Predstavljen je vpliv odplak piranske čistilne naprave, ki se stekajo vzdolž dveh podvodnih izpustov v obalno morje okoli 3500 m pred Piranom. V obdobju 1998-1999 je bilo opravljenih šest vzorčevanj, ki so vključevala oceanografske meritve, analize hranilnih snovi ter fekalnih koliformnih bakterij na postaji, ki leži sredi obeh izpustov in na referenčni postaji. Širjenje odplak v morski vodi je bilo zaznано nekaj metrov nad dnom z majhnimi, vertikalnimi spremembami slanosti (red velikosti  $-0,1$  PSU) v manj kot meter debelih slojih. Analize fekalnih bakterij, indikatorjev fekalnega onesnaženja, so potrdile lego odplak v vodnem stolpcu. Število fekalnih bakterij (max. 1160/100 ml) se je povečalo v slojih z največjimi variacijami slanosti. Največji vpliv podvodnega izpusta na obalno morje je bil opažen v primeru amonija, na ostale hranilne snovi pa širjenje odplak nima večjega vpliva. Relativno visok korelacijski koeficient je bil izračunan med fekalnimi bakterijami in amonijem ( $\rho=0,58$ ) v bližini podvodnega izpusta, medtem ko ta povezava ni bila opažena v odplakah v sami čistilni napravi ( $\rho=-0,05$ ). Referenčna postaja se je izkazala kot neustrezna, ker so se tudi tam občasno zadrževale odplake.

**Ključne besede:** odplake, podvodni izpust, fekalne bakterije, hranilne snovi, obalno morje, Tržaški zaliv

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## DIATOM ASSEMBLAGES IN COASTAL SHALLOW WATERS AT THE WATER - SEDIMENT INTERFACE (GULF OF TRIESTE, NORTH ADRIATIC SEA)

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### ABSTRACT

The resuspended microphytobenthos, mostly consisting of benthic diatoms, plays an important role in the production of  $O_2$  as a food source for pelagic and benthic grazer at the water-sediment interface of the coastal environment. In the coastal shallow waters of the Gulf of Trieste, the possible modifications in diatom community living at the water-sediment interface have been studied in respect of disturbed conditions, such as the presence of suspended mussel cultures. Two stations were chosen, one sited below the mussel rafts (st. M), the other (reference site, st. B) in an area free of cultures. The microscopic observations have shown that both stations, where mainly epipellic species belonging to the medium size class have been recorded, are characterised by the species *Cylindrotheca closterium*, *Bacillaria paxillifera* and *Gyrosigma acuminatum*. The statistical analyses have not shown significant differences as far as biodiversity of communities is concerned. However, the diatom assemblage living under the mussel cultures has been less abundant in comparison with the reference site, presumably due to the presence of benthic grazers drawn to the greater availability of organic matter owing to biodeposition.

**Key words:** Microphytobenthos, mussels, cell density, species composition, biodiversity

### INTRODUCTION

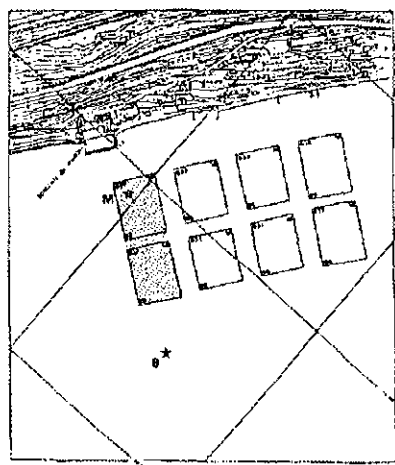
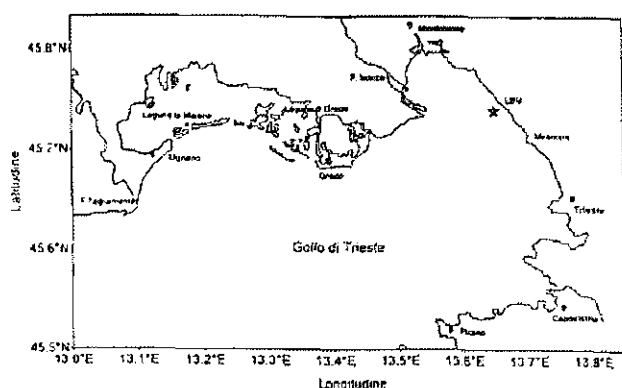
Microphytobenthos, mainly consisting of diatoms, plays an important role as the primary producer in the carbon cycle of nearshore marine sediment systems (Klepper, 1989; De Jong *et al.*, 1994). As producer of the new organic matter that can enter into the benthic and pelagic trophic web, microphytobenthos constitutes a substantial food source for sediment feeders (macro-meiobenthos) (Asmus, 1982; Admiraal *et al.*, 1983). Besides, it can be the main oxygen producer in coastal environments (Varela & Penas, 1985; Johnstone *et al.*, 1990), controlling also the oxygen balance at the water-sediment interface and allowing the aerobic degradation of autochthonous and sedimented organic matter in sediments (Davis & McIntire, 1983; Barranguet, 1997).

In the past, much research has been carried out into spatial and seasonal distribution patterns of microphytobenthos (Sundbäck, 1984, 1986; Miller *et al.*, 1987; Snoeijs *et al.*, 1990; Sundbäck & Snoeijs, 1991; De Jong & Colijn, 1994). Moreover, the sediment stabilisation by benthic diatoms and the microstructure of diatom films

have been widely studied (Grant *et al.*, 1986; Paterson, 1989). Although the term microphytobenthos suggests that these algae are confined to the sediments, their presence in the water column as a part of the phytoplankton has been well-documented (Humell, 1985; De Jonge & Van Beusekom, 1992). Recently, some studies have been undertaken to evidence the role of this resuspended microphytobenthos as an additional food source, in the water column, for pelagic filter-feeding community (De Jonge & Van Beusekom, 1992; De Jong *et al.*, 1994; Stachowitsch & Fuchs, 1995; De Jong & De Jonge, 1995).

It is known that benthic microalgae can be stirred up into the overlying water by hydrodynamic energy (tidal currents, waves and winds), becoming temporarily part of phytoplankton (De Jonge & Van Den Bergs, 1987; De Jonge, 1985; Delgado *et al.*, 1991). The resuspended algae are mainly species able to migrate actively up and down the sediment, or non-motile species reaching the sediment surface in relation to bioturbation features (Paterson, 1986, 1989; Haphey-Wood & Jones, 1988).





**Fig. 1: Position of the study area (★) and location of the reference (st. B) and the mussel culture site (st. M).  
Sl. 1: Slika območja raziskav ter lokacije (★) referenčne postaje (post. B) in nasadov užitnih klapavic (post. M).**

Several recent studies have investigated the environmental impacts of bivalve cultures regarding their role as suspension feeders that reduce the amount of phytoplankton (Frechette *et al.*, 1989; Asmus & Asmus, 1991). The massive biodeposition following the establishment of a mussel community also leads to a continuous organic enrichment of sediments, which increases the oxygen demand and may cause a temporary anoxia (Svane & Setyobudiandi, 1996; Barranguet, 1997). It has been demonstrated by many authors that organic input to the sediments enhances a net flux of inorganic nutrients to the water column with a high ammonium efflux (Klump & Martens, 1981; Rizzo, 1990; Hatcher *et al.*, 1994).

In order to identify any changes in diatom assemblages at the water sediment interface due to the presence of a suspended mussel farm, two stations have been investigated for this paper. Cell density, species composition, biodiversity and temporal patterns of diatom community in the mussel culture have been com-

pared to a nearby reference station, not influenced by mussels.

## MATERIAL AND METHODS

The study sites (st. M and B) were located in the coastal area of the Gulf, in front of the Marine Biology Laboratory (Aurisina); one sampling station was situated under suspended mussel (*Mytilus galloprovincialis*) cultures (st. M), the other (control station B) in an area of similar depth and sediment type (sandy-pelitic sediment) unaffected by cultures (Fig. 1). The water depth in the sampling sites was 12 m at st. M and 13 m at st. B.

Temperature and salinity were measured at the bottom layer by means of a Multiparameter Idronaut Ocean Seven mod. 401 probe simultaneously with biological sampling.

Sediment samples were collected at two stations at monthly intervals from May to October 1998. At each station, 3 sediment cores (8 cm diameter, 20 cm length) were taken by a diver and the overlying water was sampled using plastic syringes of 60 mL capacity. The overlying waters of the three cores were mixed together and fixed with a 4% hexamethylenetetramin-buffered formaldehyde solution. After manual stirring, subsamples of 10 mL were placed in a counting chamber, and then the viable cells at the time of fixing (with plasmatic content), were counted under a Leitz inverted light microscope and expressed as cells L<sup>-1</sup>, using the Utermöhl (1958) method.

Three replicates were counted and the absolute numbers of the viable cells were converted into relative abundance values (RA, %).

Cells were grouped into five size classes (a < 20, b 21-70, c 71-120, d 121-200 and e > 200 µm) expressed as frequency percentage (%). The different microalgae growth forms were also identified using the literature and experimental observations (Welker & Nichetto, 1996) and expressed as frequency value (%). The following life forms were particularly considered: epipellic (benthic species living on - or moving through - muddy sediments), epipsammic (adnate benthic species growing on sand grains) and planktonic (non-benthic species floating in the water column).

Scanning electron microscopy (SEM) was performed on a LEIKA CAMBRIDGE STEREOSCAN- 430i at the Department of Biology, Trieste University (Zingone *et al.*, 1990).

Community diversity and dominance were measured by the species richness (Margalef index), the Pielou's evenness index (J), the Shannon-Weaver index (H) and the Simpson index (L). The two quantitative indices (Shannon-Weaver index and Simpson index) were calculated from relative abundances, using the STADIV program (Ganis, 1991).

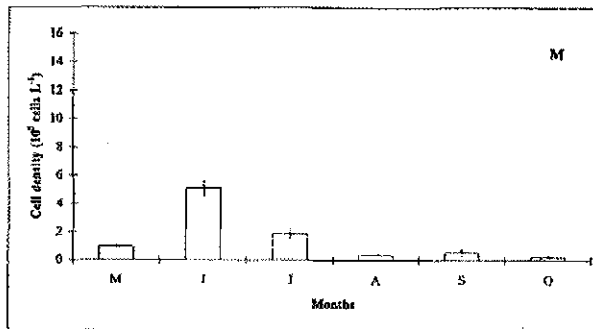
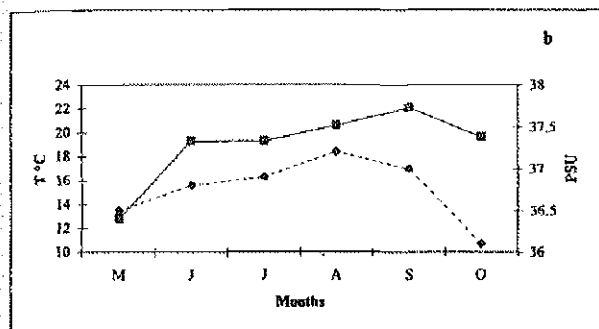
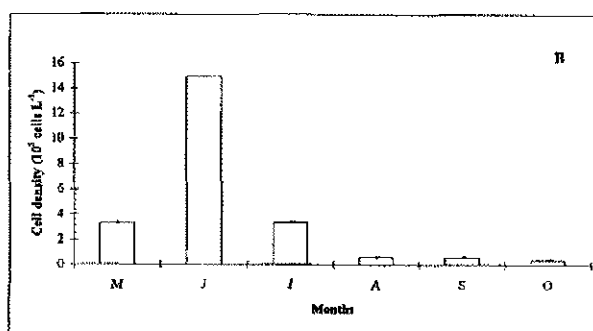
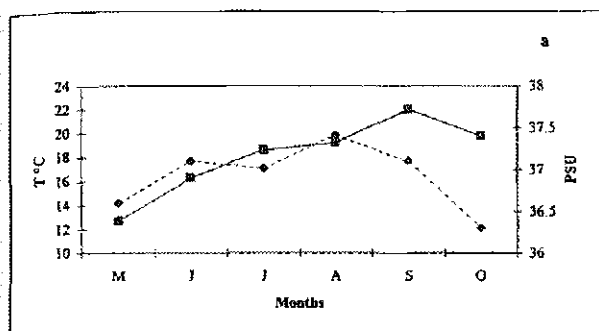


Fig. 2: Hydrological parameters recorded at the bottom layer during the sampling months at the control (a) and at the mussel cultures (b) site.

Filled squares: temperature (°C); filled rhombus: salinity (PSU).

Sl. 2: Hidrološki parametri, izmerjeni v pridnenem sloju v mesecih vzorčenja na referenčni postaji (a) in na lokaciji nasadov užitnih klapavic (b).

Črni kvadrati: temperatura (°C); črni rombi: slanost (PSU).

Fig. 3: Cell density at the control (B) and at the mussel culture (M) site during months of sampling. Standard deviations obtained from three replicates are indicated by error bars.

Sl. 3: *Gostota celic na referenčni postaji (B) in na lokaciji nasadov užitnih klapavic (M). Označene so standardne deviacije srednjih vrednosti, izračunane iz treh ponovitev.*

## RESULTS

The investigated stations were characterised, at the bottom layer, by comparable salinity values between the considered months. The temperature values showed a similar increasing trend during the samplings at the two stations, with a strong increase of about 6°C from May to June (Fig. 2).

At the mussel culture station (st. M), values of temperature slightly higher than at the control station (st. B) were recorded at all times.

The temporal pattern of the cellular abundance was quite similar between the months at the stations. The average cell density values at the reference site (st. B) were generally higher than at the mussel culture site (st. M). An average absolute maximum was recorded at the stations in June, respectively with 509333 cells l<sup>-1</sup> at station M and with 1495500 cells l<sup>-1</sup> at station B. Conversely, a minimum was recorded in October with mean values of 22333 cells l<sup>-1</sup> at station M and 37500 cells l<sup>-1</sup> at station B respectively (Fig. 3).

The size classes that appeared with constant and significant frequency were mainly of "a", "b" and "c" classes. The smallest (< 20 µm) and 21-70 µm size groups increased from May to October, whereas the medium size diatoms (71-120 µm) indicated an evident decrease. The other size classes ("d" and "e") occurred with irregular and very low frequency during all examined period (Fig. 4).

The diatom assemblages were mostly characterised by the prevalence of epipelagic species with "raphe system"; these motile diatoms varied in mean frequency from 49.7% to 96.7% at station M and from 70.7% to 98.0% at station B (Fig. 5). The epipsammic growth forms, consisting of diatoms attached firmly to the substrate, appeared with a mean relative frequency always higher at the mussel cultures site in respect to the reference site, reaching the highest frequency (49.8%) in July. Living planktonic species were constantly present at both locations with a variation ranging from 0.5% to 3.8% at station M and from 0.2% to 14.2% at station B. Nevertheless, the highest mean frequency (14.2%) of

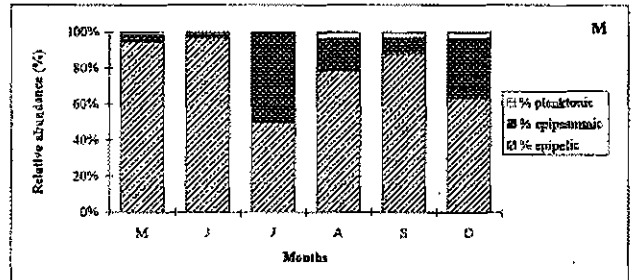
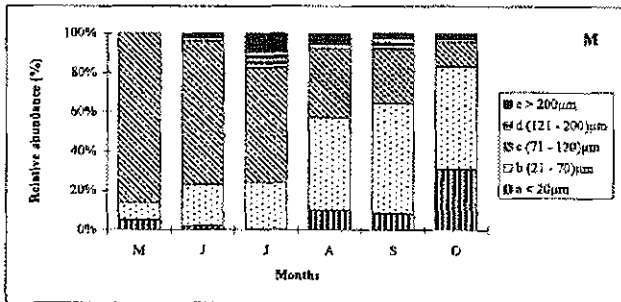
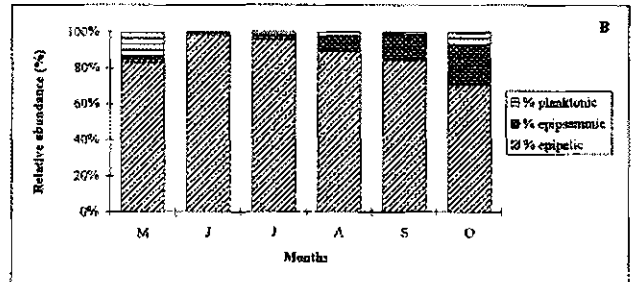
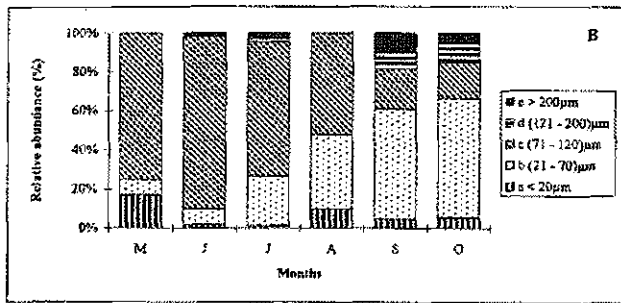


Fig. 4: Relative abundance of size groups at the control (B) and at the mussel cultures (M) site. All values are means of three replicates.

Sl. 4: Relativna abundanca velikostnih razredov na referenčni postaji (B) in na lokaciji nasadov užitnih klapavic (M). Vse vrednosti so srednje vrednosti treh ponovitev.

Fig. 5: Change in life forms frequency (%) at the control (B) and at the mussel cultures (M) site. All values are means of three replicates.

Sl. 5: Spremembe v frekvenci življenjskih oblik (%) na referenčni postaji (B) in na lokaciji nasadov užitnih klapavic (M). Vse vrednosti so srednje vrednosti treh ponovitev.

planktonic species was recorded at the control station (st. B) in May (Fig. 5).

The two sampling sites were characterised by the presence of the following epipelic species: *Cylindrotheca closterium* (EHR.) REIMANN & LEWIN, *Bacillaria paxillifera* (O. F. MÜLL.) HENDEY and *Gyrosigma acuminatum* (KUNTZ.) RABENHORST (Figs. 6 a-f).

At the control station, *C. closterium* showed the highest relative abundance in June with the mean value of 82.05%, while *B. paxillifera* and *G. acuminatum* reached the highest values in July (mean RA 16.37% and 18.16%). The relative abundance of these three species was followed by a progressive decrease during the other months (Tab. 1, Fig. 7).

At the mussel culture station, comparable relative abundances were noted. In particular *C. closterium* reached its maximum in May (mean RA 84.15%), while *B. paxillifera* and *G. acuminatum* reached it in August (mean RA 19.25%) and September (mean RA 19.88%) respectively. In spite of the constant presence of *B. paxillifera* and *G. acuminatum* at both stations during the sampling period (May-October), *C. closterium* was never found on either site (Tab. 1, Fig. 7). These species may be considered characteristic of the diatom-assemblages living at the water-sediment interface, in order to determine the features of the community, even if they

are not necessarily the most abundant species. These communities may be even defined by merely one of the characteristic species.

The epipsammic forms detached with large amounts were mainly characterised by the genera *Amphora* and *Navicula*. Particularly at station M, *Amphora* was the prevalent genus in July (mean RA 48.15%) with the highest percentage of *A. ostrearia* De BREBISSON (mean RA 46.98%; Tab. 1, Fig. 5).

The diatom communities at the water-sediment interface showed similar values in species richness (Margalef index) at both sites. The absolute maximum was recorded in September (3.4) at station B and in July (3.3) at station M, whereas the absolute minimum was noticed in August (1.5) at station B and in May (1.3) at station M.

The evenness measures ranged from 0.2 to 0.8 at the reference site, while at the mussel site they ranged from 0.3 to 0.8. Pielou's index values showed a similar temporal pattern to H-values, indicating that abundance was more evenly distributed among the species from May to October. The species abundance was unevenly distributed in June (0.2) and in May (0.3) at B and M sites respectively, as indicated by the very low Pielou's index values. A better abundance distribution among the species was evident in September at station B and in August at station M with the corresponding values near to one.

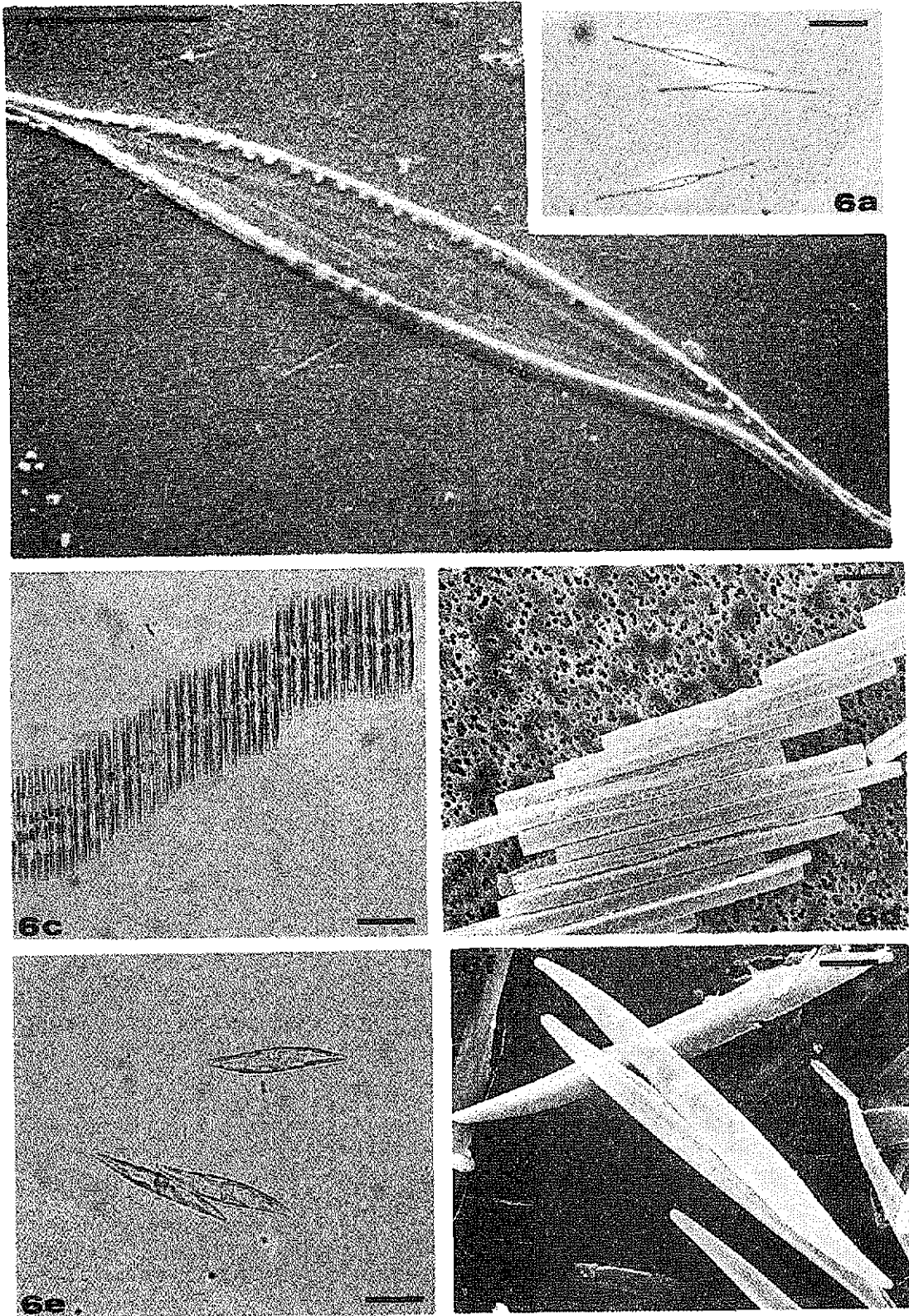


Fig. 6: Micrographs by inverted light and scanning electron microscope of following characteristic species: *Cylindrotheca closterium* (a-b), *Bacillaria paxillifera* (c-d) and *Gyrosigma acuminatum* (e-f). Scale bar (a, c and e) = 33  $\mu\text{m}$ ; (b, d and f) = 10  $\mu\text{m}$ .

Sl. 6: Posnetki invertnega svetlobnega mikroskopa in elektronskega mikroskopa značilnih vrst: *Cylindrotheca closterium* (a-b), *Bacillaria paxillifera* (c-d) in *Gyrosigma acuminatum* (e-f). Merilo (a, c in e) = 33  $\mu\text{m}$ ; (b, d in f) = 10  $\mu\text{m}$ .

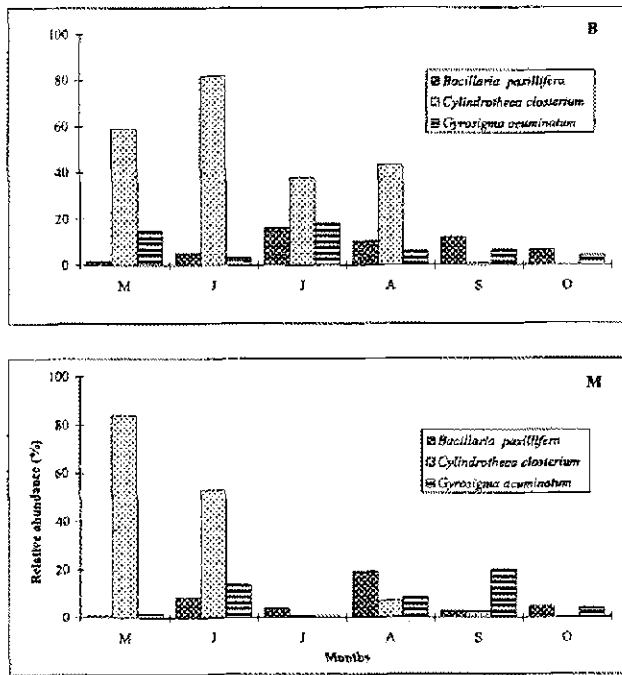


Fig. 7: Relative abundance of characteristic species at the control (B) and at the mussel cultures (M) site. All frequency values are means of three replicates.

Sl. 7: Relativna abundanca značilnih vrst na referenčni postaji (B) in na lokaciji nasadov užitnih klapavic (M). Vse vrednosti so srednje vrednosti treh ponovitev.

The Shannon-Weaver's diversity (H) index varied between 0.9 and 3.0 at site B, whereas at site M the same index varied between 0.8 and 2.7. The H-values showed an increasing trend from May to October at both sites. At the two stations the highest diatoms community biodiversity (H) was reached at different times. In particular at station B, the Shannon-Weaver index was equal to 3.0 in September, while at the other station the highest value was recorded in August (H = 2.7). Inversely, the lowest H-index values were recorded in June (H = 0.9) and in May (H = 0.8) at sites B and M respectively.

The Simpson index values showed an evident opposite temporal trend in view of the trend observed for the Shannon-Weaver index. The lowest Simpson index values were reached in September at st. B (L = 0.07) and in August at st. M (L = 0.09), the months in which the highest H-values were revealed. As these quantitative indices are inversely correlated, this corresponds with the absence of any dominant species. In addition, the highest L-index values (0.67 at st. B in June and 0.71 at st. M in May) together with the lowest H-index values were registered in the same months, indicating a clear dominance of some species (Tab. 2).

## DISCUSSION

The between-site differences in total cell density indicated that the diatoms community at the water-sediment interface, affected by the mussel cultivations, was always less abundant than the one observed at the reference site. The diatom assemblage under the suspended mussel cultures seemed to be limited in growth, in spite of the enhanced sedimentation of organic material and furthermore active nutrients regeneration at the water-sediment interface (Klump & Martens, 1981; Rizzo, 1990; Hatcher et al., 1994; Svane & Setyobudiandi, 1996). On the other hand, the sediments are usually considered an inexhaustible source of inorganic nutrients for benthic algae so that nutrient limitation should not arise (Sundbäck, 1986; Sundbäck & Snoeijs, 1991). The lower diatom abundance, at the mussel site, could be explained by considering the presence of the other limiting factors. As already seen by several authors (Sundbäck, 1986; Paterson, 1986; De Jonge & Colijn, 1994), light intensities may be considered a limiting factor for microphytobenthos, which can survive shading for long periods and recover rapidly when light conditions improve. The mussel site, although placed at a lower depth than the other one (st. B) and also conditioned by higher bottom temperature, might be unfavourable to photosynthetic activity, presumably for a diminished light irradiance at the bottom layer. This limitation might be due to the shading effect of the floating mussel systems and the continuous release and biodeposition of organic matter (faeces and pseudofaeces) from the water column to the bottom layer. As far as the incident light intensity reaching the water sediment interface is concerned, Barranguet (1997) highlighted, in a recent study on microphytobenthic primary production in a mussel culture, that the incident light percentages lower at a mussel station than at a reference station are a limiting factor for microphytobenthos production. Besides, enriched sediments by biodeposition are usually inhabited by a quantitatively rich associated fauna consisting of both infauna in the sediment and attached epifauna on the shells (Svane & Setyobudiandi, 1996).

In addition, direct underwater observations showed that the soft-bottom under the investigated mussel cultures was covered by living mussels and shells that had fallen down from the rafts. This modified substrate was an optimal support of adhesion for the settling of epibenthic communities. This community, known as O-R-M (*Ophiothrix*, *Reniera* and *Microcosmus* genus) community (Stachowitsch & Fuchs, 1995), was largely made of mobile and sessile filter or suspension feeders that had aggregated in the form of the so-called multi-species clumps (F. Aleffi, pers. comm.). Therefore, the diatom community living at the water-sediment interface below the mussel site might be subject to a major selec-



| Diatom taxon   | Control station (st. B) |      |      |      |      |      | Mussel culture station (st. M) |      |      |      |      |      |
|--|-------------------------|------|------|------|------|------|--------------------------------|------|------|------|------|------|
|  | M                       | J    | J    | A    | S    | O    | M                              | J    | J    | A    | S    | O    |
| <i>Amphora coffeaeformis</i> (Agardh) Kützing                | 0,2                     | 0,2  | -    | 0,3  | 0,9  | 1,3  | 1,4                            | 0,9  | 0,9  | 2,3  | 0,6  | 3,7  |
| <i>Amphora ostrearia</i> de Brébisson                        | -                       | -    | 0,2  | -    | 2,9  | 0,4  | -                              | -    | 47,0 | 11,7 | 1,2  | 0,7  |
| <i>Amphora ovalis</i> (Kützing) Kützing                      | 0,1                     | -    | 0,1  | 0,3  | 2,6  | 2,2  | 0,2                            | 0,4  | 0,3  | -    | 1,2  | 0,7  |
| <i>Amphiprora alata</i> Kützing                              | -                       | -    | -    | -    | -    | -    | -                              | -    | 0,2  | -    | -    | -    |
| <i>Amphiprora paludosa</i> W. Smith                          | -                       | -    | 0,0  | -    | -    | -    | -                              | -    | 0,1  | -    | -    | -    |
| <i>Bacillariapaxillifera</i> (O. F. Müller) Hendey           | 1,6                     | 5,2  | 16,4 | 10,2 | 12,0 | 6,7  | 0,7                            | 8,6  | 3,8  | 19,2 | 2,8  | 4,5  |
| <i>Campylodiscus</i> sp.                                     | -                       | 0,0  | 1,2  | 0,3  | -    | 2,7  | -                              | 0,5  | -    | -    | -    | 2,2  |
| <i>Cocconeis placentula</i> Ehrenberg                        | -                       | -    | -    | -    | -    | -    | -                              | -    | 0,3  | -    | -    | -    |
| <i>Cocconeis</i> sp.   | -                       | -    | -    | -    | 0,3  | 0,4  | -                              | -    | -    | -    | -    | 1,5  |
| <i>Cyclotella</i> sp.  | -                       | -    | 0,1  | -    | -    | -    | -                              | -    | -    | -    | -    | -    |
| <i>Cylindrotheca closterium</i> (Ehrenberg) Reimann et Lewin | 59,0                    | 82,1 | 37,9 | 43,3 | 0,9  | -    | 84,2                           | 53,0 | 0,5  | 7,0  | 2,4  | -    |
| <i>Cymbella</i> cf. <i>cistula</i> (Hemprich) Grunow         | -                       | -    | 0,3  | -    | -    | -    | -                              | -    | -    | -    | -    | -    |
| <i>Cymbella</i> sp.  | -                       | -    | -    | 0,8  | 1,4  | 0,9  | -                              | 0,1  | 0,2  | -    | 0,3  | -    |
| <i>Diploneis bombus</i> Ehrenberg                            | -                       | 0,0  | -    | 0,3  | -    | 0,9  | -                              | -    | -    | -    | 0,3  | -    |
| <i>Diploneis crabro</i> Ehrenberg                            | -                       | -    | -    | -    | -    | -    | -                              | 0,2  | -    | -    | -    | -    |
| <i>Diploneis ovalis</i> (Hilse) Cleve                        | 0,3                     | 0,0  | 0,9  | 1,9  | 2,0  | -    | 0,5                            | 0,6  | 0,3  | -    | 0,6  | 6,0  |
| <i>Diploneis smithii</i> (de Brébisson) Cleve                | 0,2                     | 0,0  | 0,2  | -    | 1,4  | 0,9  | 0,4                            | -    | 0,3  | 1,9  | 0,6  | -    |
| <i>Diploneis</i> sp.   | -                       | 0,0  | -    | -    | 0,3  | -    | -                              | -    | -    | -    | -    | -    |
| <i>Eunotia</i> sp.   | -                       | -    | -    | -    | -    | 9,8  | -                              | -    | -    | -    | -    | -    |
| <i>Grammatophora</i> sp.                                     | -                       | 0,0  | -    | -    | -    | -    | -                              | -    | 0,3  | -    | -    | -    |
| <i>Gyrosigma acuminatum</i> (Kützing) Rabenhorst             | 14,8                    | 3,3  | 18,2 | 6,2  | 6,9  | 4,0  | 1,6                            | 13,9 | 0,8  | 8,5  | 19,9 | 3,7  |
| <i>Gyrosigmafasciola</i> (Ehrenberg) Griffith et Henfrey     | 0,1                     | -    | 0,8  | -    | 0,6  | -    | 0,2                            | 4,6  | -    | -    | -    | -    |
| <i>Gyrosigma macrum</i> W. Smith                             | -                       | 0,0  | 0,4  | -    | 0,6  | 1,3  | -                              | 0,4  | 4,5  | 1,4  | 2,4  | 1,5  |
| <i>Gyrosigma obliquum</i> (Grunow) Boyer                     | -                       | -    | -    | -    | -    | -    | -                              | -    | 0,4  | -    | -    | -    |
| <i>Licmophora gracilis</i> Grunow                            | -                       | 0,0  | -    | -    | -    | -    | -                              | -    | -    | -    | -    | -    |
| <i>Licmophora</i> sp.  | -                       | -    | -    | -    | -    | 0,4  | -                              | -    | -    | -    | -    | 0,7  |
| <i>Melosira moniliformis</i> (O. F. Müller) Agardh           | -                       | 0,1  | 0,3  | -    | 14,6 | 7,1  | 1,8                            | 3,5  | 1,1  | -    | 3,1  | 3,0  |
| <i>Navicula cancellata</i> Donkin                            | -                       | -    | -    | -    | 0,3  | -    | -                              | -    | -    | -    | -    | -    |
| <i>Navicula</i> cf. <i>directa</i> (W. Smith) Ralfs          | 1,3                     | 1,0  | 2,3  | 4,8  | 8,9  | 5,3  | 0,7                            | 2,5  | 2,7  | 4,7  | 3,1  | -    |
| <i>Navicula simulans</i> Donkin                              | 0,1                     | 0,1  | 0,8  | -    | 2,6  | 4,0  | -                              | 0,4  | 0,3  | -    | -    | -    |
| <i>Navicula</i> sp. 1  | 2,6                     | 1,5  | 0,8  | 7,3  | 2,3  | 4,0  | 3,2                            | 1,6  | 0,3  | 5,2  | 4,6  | 29,1 |
| <i>Navicula</i> sp. 2  | 2,0                     | 0,3  | 1,5  | 16,4 | 5,4  | 21,3 | 1,9                            | 1,1  | 5,0  | 12,2 | 35,5 | 15,7 |
| <i>Navicula</i> sp. 4  | -                       | -    | -    | -    | -    | -    | -                              | -    | -    | 0,9  | -    | -    |
| <i>Navicula</i> sp. (tubo)                                   | -                       | 0,0  | -    | -    | -    | -    | -                              | -    | -    | -    | -    | -    |
| <i>Nitzschia angularia</i> (A. Schmidt) W. Smith             | -                       | 0,1  | 0,9  | -    | 2,6  | -    | -                              | -    | 1,1  | -    | 1,2  | -    |
| <i>Nitzschia gracilis</i> Hantzsch                           | -                       | 0,3  | 0,8  | -    | -    | 0,4  | -                              | 0,5  | 0,4  | 0,5  | -    | -    |
| <i>Nitzschia irresoluta</i> Hustedt                          | 0,3                     | 0,5  | 0,2  | -    | 1,4  | 0,9  | -                              | -    | 2,0  | 1,4  | 1,5  | 2,2  |
| <i>Nitzschia lanceola</i> Grunow                             | -                       | 0,1  | 0,3  | -    | -    | 0,4  | -                              | 0,1  | -    | -    | -    | -    |
| <i>Nitzschia longissima</i> (de Brébisson) Ralfs             | -                       | 0,1  | 0,2  | -    | 0,6  | 0,9  | -                              | 0,3  | 0,1  | -    | -    | -    |
| <i>Nitzschia lorenziana</i> Grunow                           | 0,3                     | 0,9  | 0,8  | 0,3  | 1,4  | 0,4  | 0,2                            | 0,2  | 2,7  | 3,8  | 1,2  | -    |
| <i>Nitzschia obtusa</i> (A. Schmidt) W. Smith                | -                       | 0,1  | 0,6  | -    | 0,6  | -    | -                              | -    | -    | -    | -    | -    |
| <i>Nitzschia</i> cf. <i>palea</i> (Kützing) W. Smith         | -                       | -    | -    | -    | 1,1  | -    | -                              | -    | -    | -    | -    | -    |
| <i>Nitzschia panduri</i> Jormis Gregory                      | 0,2                     | -    | 0,1  | -    | -    | -    | -                              | 0,1  | 0,2  | -    | -    | 2,2  |
| <i>Nitzschia recta</i> Hantzsch                              | 0,3                     | 0,8  | 1,0  | 0,8  | 0,3  | 2,7  | 0,5                            | 1,8  | 2,4  | 1,9  | 1,8  | 2,2  |
| <i>Nitzschia sigma</i> (Kützing) W. Smith                    | 0,4                     | 1,1  | 8,6  | 1,3  | 5,1  | 4,0  | -                              | 2,4  | 2,5  | 4,7  | 1,8  | 4,5  |
| <i>Nitzschiasigma</i> var. <i>intercedens</i> Grunow         | -                       | -    | -    | -    | -    | -    | -                              | 0,1  | 1,6  | -    | 0,3  | -    |
| <i>Nitzschiasigma</i> var. <i>sigmatella</i> Grunow          | -                       | -    | -    | -    | -    | -    | -                              | 0,5  | 1,4  | -    | -    | -    |
| <i>Nitzschia sigmoidea</i> (Ehrenberg) W. Smith              | 0,1                     | 0,1  | 0,5  | -    | 6,6  | -    | -                              | 1,1  | 1,4  | 1,4  | 1,2  | -    |
| <i>Nitzschia tryblionella</i> Hantzsch                       | 1,1                     | 0,8  | 0,9  | 3,0  | 3,7  | 7,6  | 0,5                            | 1,5  | 3,1  | 4,2  | 5,5  | 8,2  |
| <i>Nitzschia vermicularis</i> (Kützing) Grunow               | -                       | 0,7  | 0,5  | -    | 4,6  | -    | -                              | 1,4  | 1,4  | 0,9  | 1,2  | -    |
| <i>Pinnularia</i> cf. <i>leptosoma</i> Grunow                | 0,2                     | -    | -    | -    | 0,3  | -    | -                              | 0,3  | -    | -    | -    | -    |
| <i>Pinnularia viridis</i> (Nitzsch) Ehrenberg                | -                       | 0,0  | -    | -    | -    | -    | -                              | 0,3  | -    | 0,5  | -    | -    |
| <i>Pinnularia</i> sp.  | -                       | -    | 0,3  | -    | -    | -    | -                              | -    | -    | -    | -    | -    |
| <i>Pleurosigma aestuarii</i> (de Brébisson) W. Smith         | -                       | -    | -    | -    | -    | 0,9  | -                              | 0,3  | -    | -    | -    | 0,7  |
| <i>Pleurosigma angulatum</i> (Quekett) W. Smith              | -                       | -    | -    | -    | 0,3  | -    | -                              | -    | -    | -    | -    | -    |
| <i>Pleurosigma formosum</i> W. Smith                         | -                       | -    | 0,4  | -    | -    | -    | -                              | 0,1  | 0,5  | 0,5  | -    | -    |
| <i>Pleurosigma minutum</i> Grunow                            | -                       | -    | -    | -    | -    | -    | -                              | -    | 0,3  | -    | -    | -    |

|   |      |     |     |     |     |     |     |     |     |     |     |     |
|---|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>Proboscia alata</i> (Brightwell) Sundström     | -    | 0,0 | -   | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| <i>Rhopalodia gibba</i> (Ehrenberg) O. Müller     | 0,1  | 0,0 | -   | -   | 0,3 | 1,3 | -   | 0,2 | -   | -   | 0,6 | -   |
| <i>Surirella</i> sp.                              | -    | -   | 0,7 | -   | -   | -   | -   | 0,3 | 0,1 | -   | -   | -   |
| <i>Synedra</i> sp.                                | -    | -   | -   | -   | -   | 3,1 | -   | -   | -   | -   | -   | -   |
| <i>Thalassiosira eccentrica</i> (Ehrenberg) Cleve | 0,2  | 0,0 | -   | -   | 0,3 | 0,9 | 0,7 | -   | 0,4 | 0,9 | 0,3 | 2,2 |
| <i>Thalassiosira</i> sp.                          | 14,2 | 0,1 | 0,3 | 2,4 | 1,1 | 1,3 | 1,6 | 0,3 | 0,5 | 3,8 | 3,7 | 1,5 |
| <i>Triceratium</i> sp.                            | -    | -   | -   | -   | 0,3 | -   | -   | -   | -   | -   | -   | -   |
| <i>Tropidoneis lepidoptera</i> (Gregory) Cleve    | -    | -   | 0,3 | -   | -   | -   | -   | -   | -   | -   | 0,3 | 3,0 |
| <i>Tropidoneis longa</i> Cleve                    | -    | -   | 0,3 | -   | -   | -   | -   | -   | -   | -   | -   | -   |
| <i>Tropidoneis</i> cf. <i>longa</i> Cleve         | -    | -   | -   | -   | 2,0 | -   | -   | -   | 2,2 | -   | -   | -   |
| <i>Tropidoneis</i> sp.                            | 0,2  | 0,0 | -   | 0,3 | 0,9 | 1,3 | -   | 0,3 | 2,0 | 0,5 | 0,6 | -   |

Tab. 1: List of diatom taxa with mean relative abundance value (%).

Tab. 1: Seznam diatomejskih vrst in njihove relativne vrednosti abundance (%).

Site B:

| Date | Mean cell densities (cells L <sup>-1</sup> ) | Number of species | Species richness evenness | Pielou's index (J) | Shannon-Weaver index (H) | Simpson index (L) |
|------|--|-------------------|---------------------------|--------------------|--------------------------|-------------------|
| M    | 331000                                       | 24                | 1,8                       | 0,4                | 1,4                      | 0,39              |
| J    | 1496000                                      | 36                | 2,5                       | 0,2                | 0,9                      | 0,67              |
| J    | 334000                                       | 36                | 2,8                       | 0,6                | 2,1                      | 0,21              |
| A    | 62000  | 18                | 1,5                       | 0,7                | 1,9                      | 0,24              |
| S    | 58340  | 38                | 3,4                       | 0,8                | 3,0                      | 0,07              |
| O    | 37500  | 32                | 2,9                       | 0,8                | 2,9                      | 0,08              |

Site M:

| Date | Mean cell densities (cells L <sup>-1</sup> ) | Number of species | Species richness evenness | Pielou's index (J) | Shannon-Weaver index (H) | Simpson index (L) |
|------|--|-------------------|---------------------------|--------------------|--------------------------|-------------------|
| M    | 94670  | 16                | 1,3                       | 0,3                | 0,8                      | 0,71              |
| J    | 509300                                       | 36                | 2,7                       | 0,5                | 1,9                      | 0,31              |
| J    | 185200                                       | 41                | 3,3                       | 0,6                | 2,4                      | 0,24              |
| A    | 35500  | 24                | 2,2                       | 0,8                | 2,7                      | 0,09              |
| S    | 54500  | 29                | 2,6                       | 0,7                | 2,4                      | 0,18              |
| O    | 22330  | 22                | 2,1                       | 0,8                | 2,5                      | 0,13              |

Tab. 2: Summary tables of statistic indices calculated from relative abundance, using the STADIV program.

Tab. 2: Pregled statističnih indeksov, izračunanih iz relativne abundance z uporabo STADIV programa.

tive pressure by benthic invertebrates (Asmus, 1982; Admiraal *et al.*, 1983; De Jong *et al.*, 1994).

The highest total abundances showed by the diatom assemblage at the water-sediment interface in June were probably due to the sudden increase in temperature in the study area. As already demonstrated, changes in temperature seem to be correlated with the increase of microphytobenthic density, until blooming begins at the water-sediment interface (De Jong & Admiraal, 1984; Dellavalle *et al.*, 1993; De Jong & De Jonge, 1995; Welker & Nichetto, 1996).

The relative minimum in diatoms abundance according to our results in October might be related to physical variations, such as light attenuation and vertical instability of the overlying water due to the active mixing of the winds, cooling and mechanical stirring. In fact, water column stratification that was established in May

was not recorded from September on; the overlying water appeared homogeneous and remained constantly unstratified during the ensuing months. In addition, few days before October sampling, an aggravation of the meteorological conditions (characterised by low barometric pressure, increasing precipitation and wind intensity) was recorded (M. Celio, *pers. comm.*). Therefore all these physical variations could act as a disturbance phenomenon in diatom community monitored, as already seen by Dellavalle *et al.* (1993) for a fouling community of the Gulf of Trieste.

Besides, due to some previous studies (Hudon & Bourget, 1983; Dellavalle *et al.*, 1993) we also know that physical disturbance, in diatom assemblage, leads usually to a fall in highly motile and chain forming species in diatom community. This observation would be in agreement with our results concerning growth of life

forms. In fact, in fall, the epipelagic species reached their minimum frequency favouring the epipsammic growth forms development, presumably better adapted to existence under unfavourable conditions (such as low light intensity or very fast current) and continual disturbance (Miller *et al.*, 1987; Paterson, 1989).

However, the presence of epipelagic species at the water-sediment interface is probably linked to the vertical active migrations towards the sediment surface that take place whenever the sediment is disturbed, finding a way out into the overlying water. Besides, a highly stimulated photosynthetic activity at the sediment surface may in itself function as a selective pressure on the microalgal community by selectively transporting away easily suspendible species (Sundbäck & Snoeijs, 1991). Conversely, when the conditions at the water-sediment interface are not yet favourable, owing to chemical and physical variations, these motile diatoms are able to take cover in the sediment. On the other hand, De Jonge (1985) highlights how the capacity of epipelagic diatoms to migrate could be interpreted as a survival strategy to prevent populations from being resuspended. These considerations, which were eventually confirmed by other authors (Paterson, 1986; De Jonge & Van Den Bergs, 1987; Happey-Wood & Jones, 1988; Delgado *et al.*, 1991; De Jong & De Jonge, 1995), would explain the decrement in epipelagic species frequency, proceeding from the summer stability to the fall unfavourable situation. Adversely, the epipsammic species, firmly bound to the substrate with persistent mucilaginous attachment structures, would be found at the water-sediment interface only after stirred up by hydrodynamic forces. This would explain their higher abundance at the end of summer and early autumn, periods characterised by an increasing instability at the bottom layer (M. Celio, *pers. comm.*). Besides, the epipsammic percentage values, greater at the mussel culture station than at the reference station, might be a result of the changed substrate conditions which, for the presence of the mussel shells and their harvesting remains, could act as an additional adhesion support. Similar results were already obtained in the recent work by Barranguet (1997), in which he highlighted how under the mussel culture area the microphytobenthos is composed mainly of diatoms, with a high abundance of epiphytic forms.

The planktonic species, which can be found at the water-sediment interface, are usually the consequence of the sinking phenomena involving either the vegetative cells at the end of the blooming period or the resting cells (non-growing diatom cells) (Smayda, 1971; Smetacek, 1985). During our investigation, these diatoms appeared to be slightly more abundant at the reference site than at the mussel culture site, suggesting that phytoplankton biomass is probably influenced by the presence of these filter feeders (Fréchet *et al.*, 1989; Asmus & Asmus, 1991). Large amounts of planktonic

diatoms were particularly evident in May, at the reference site, following the spring diatom bloom at the subsurface layer (S. Cok, *pers. comm.*).

The temporal increasing pattern of the smallest and medium-small diatoms could be related to the corresponding increase in temperature at the bottom layer. The specific growth rate,  $\mu$ , is a convenient parameter for characterising the growth potential of a species as a function of environmental variables and it provides a means of comparing one species with another. Among the environmental factors, temperature is the main variable that can affect the growth rate of diatoms. Each species show a maximum specific growth rate, probably genetically determined, at its temperature optimum. Changes in temperature affect the specific microalgal growth rate, inducing slight shift within both the planktonic and benthic communities. In addition, larger cells grow at a slower rate than small-celled species of both pennate and centric diatoms. Therefore, small size diatoms respond more quickly to a sudden rise in temperature with respect to the larger ones. A benthic diatom community can modify its composition, especially within size classes, when changes in temperature occur (Eppley, 1977). In natural environment, small size diatoms can have precedence over the larger ones and can characterise the whole community (Malone *et al.*, 1993).

As regards species composition, the diatom communities described in this study did not show substantial differences, as confirmed by similar richness values. These diatom assemblages are typical of muddy sediment in the Gulf of Trieste, and comparable to those found by Welker & Nichetto (1996) in deeper offshore waters in the same area.

Since variation in diatom species composition is a good indicator of the environmental condition (Snoeijs *et al.*, 1990), the large amounts of epipsammic species *A. ostrearia* (only at the mussel culture site) suggest that this species seems to prefer enriched sediments with higher organic content. On the other hand, *A. ostrearia* was often found, in large quantities, in oyster-bed culture (Maestrini & Robert, 1987), perhaps favoured by photoheterotrophic growth at low light intensities (Admiraal *et al.*, 1984; Sundbäck, 1986).

Although the density of benthic diatoms is apparently not correlated with nutrient availability at the bottom layer, it seems to be influenced to a certain extent by the changes in temperature (De Jong & Admiraal, 1984; Sundbäck, 1986; Sundbäck & Snoeijs, 1991; Dellavalle *et al.*, 1993; De Jong & De Jonge, 1995; Welker & Nichetto, 1996). However, the species *C. closterium* seems positively affected by nutrient availability. In fact, it reached the maximum abundance value in early summer, period characterised by highest ammonium and phosphate concentration at the bottom layer (S. Predonzani, *pers. comm.*). This is in agreement

with previous observations, in which highly motile *C. closterium* cells were able to benefit from the inorganic nutrient enrichment and laboratory experiments that also showed their capability to increase its growth rate with higher salinity and temperature (Jong & Admiraal, 1984; Sundbäck & Snoeijs, 1991).

The between-site variation of diversity was small, but slightly lower diversity at the mussel culture site might have been caused by a combination of several factors, such as the occurrence of intense mechanical disturbance by grazing, shading effect, high organic content, etc. The slight decrease in diversity that according to some previous studies occurred near the shore could perhaps be interpreted as an indicator of stress, such as from organic pollution (Pielou, 1975). Decrease in diversity has also been observed in benthic diatom communities under eutrophic conditions (Sundbäck, 1984). Although there are few studies that overlook diatom communities diversity of mud substrates, the Shannon-Weaver's index values obtained during our investigations were comparable to those reported for diatom communities of sandy substrates (Sundbäck & Snoeijs, 1991). The Simpson index values also confirmed the net dominance of *C. closterium*, above all in early summer, at both sites.

### CONCLUSIONS

The assemblages of diatoms at the water-sediment interface were at both investigated stations composed mainly of epipelagic species belonging to the medium size group, represented by the following characteristic spe-

cies: *C. closterium*, *B. paxillifera* and *G. acuminatum*.

Regarding the possible effects of the presence of the suspended mussel cultures on the two diatom communities, no evident variations were noted during the study regarding the species composition as underlined by Margalef index, and temporal pattern. The only disturbing effect due to the presence of mussel rafts, which also causes a between-site dissimilarity, was noted in algal cell density. In spite of a rather similar biodiversity index value (Shannon-Weaver index) within both stations, the lower diatom abundance observed at the mussel site might be due indirectly to their presence. Among all the disturbance factors, such as shading effect, biodeposition and grazing by benthic animals, the latter is the only one that does not affect the species composition of the diatom assemblages. A light attenuation at the bottom layer, generally, can favour some shading-adapted species. On the other hand, the continuous deposition of organic matter (faeces and pseudofaeces) may select some species characterised by a photoheterotrophic metabolism. Suspension and filter feeders invertebrates are not able to select the desirable diatom species, as food source, so the grazing effect on the community at the water-sediment interface is relevant only for the cell abundance.

Therefore it can be assumed that the diatom community under the suspended mussel cultures is limited in cell density due to a larger grazing activity by the rich associated fauna, drawn to higher availability of organic matter, and by filter-feeders of epibenthic O-R-M community.

## KOPIČENJE DIATOMEJ NA VMESNI PLASTI VODNIH USEDLIN V OBALNIH VODAH TRŽAŠKEGA ZALIVA (SEVERNI JADRAN)

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### POVZETEK

Resuspendirani mikrofitobentos, ki sestoji predvsem iz bentoških diatomej, igra pomembno vlogo v proizvodnji  $O_2$  kot hrane za pelagične in bentoške prehranjevalce na vmesni plasti vodnih usedlin v morskem obrežnem okolju. Da bi preverili morebitne spremembe v kopičenju diatomej na vmesni plasti vodnih usedlin zaradi tam domujočih suspendiranih kultur užitnih klapavic, je bilo opravljenih več raziskav na dveh izbranih postajah v Tržaškem zalivu. Mikroskopske analize so pokazale, da so za obe postaji, kjer so bile zabeležene predvsem epipelagične vrste srednje velikosti, značilne vrste *Cylindrotheca closterium*, *Bacillaria paxillifera* in *Gyrosigma acuminatum*. Statistične analize niso pokazale kakih večjih razlik glede biotske pestrosti teh združb. Pa vendar so bile diatomeje, živeče pod kulturami užitnih klapavic, manj številne, če jih primerjamo s tistimi na referenčnih postajah, nemara zaradi pojavljanja bentoških prehranjevalcev, ki jih je privabila večja razpoložljivoist organskih snovi zaradi biodepozicije.

**Ključne besede:** mikrofitobentos, školjke, gostota celic, vrstna sestava, biodiverzitet

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## SEASONAL AND LONG-TERM VARIABILITY OF MEIOFAUNA IN THE ENVIRONMENT FREQUENTLY AFFECTED BY HYPOXIA IN CENTRAL PART OF THE GULF OF TRIESTE

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### ABSTRACT

*The article deals with benthic meiofauna studied for three years in central part of the Gulf of Trieste. The obtained results present meiofauna's seasonal reproduction cycles and long-term trends in these cycles. The seasonal dynamics was in positive correlation with thermal conditions and salinity, and in negative correlation with oxygen and phytoplankton's chlorophyll in the bottom-water layer. A 2-month lag in meiofauna's dynamics was noted behind phytoplankton's seasonal cycle (spring and autumn blooms), while at a long-term scale a 3-year trend of growth in meiofauna's mean yearly abundances was observed.*

**Key words:** seasonal dynamics, benthic meiofauna, Gulf of Trieste

### INTRODUCTION

Meiofauna's seasonal dynamics is one of most often investigated topics as far as benthic fauna is concerned. The situation is quite different when dealing with long-term changes in meiofaunal communities, which have been studied to a much lesser extent, particularly periods exceeding one year. Such up to ten years lasting studies have been presented in various works, e.g. by Coull (1985, 1986), Eskin & Coull (1987), Rudnick *et al.* (1985), in contrast to numerous one year long investigations in coastal environments comparable with our coastal waters (e.g. Bovee & Soyler, 1974; Harris, 1972).

The research on meiofauna occurring in the Slovene part of the Gulf of Trieste has been till now focused on both topics, *i.e.* on its seasonal dynamics as well as on its long-term changes. In the latter we were involved for the first time in the 1992-1995 period, namely in connection with elsewhere poorly researched impacts of the lack of bottom-water oxygen (hypoxia and anoxia) on meiobenthos. The results of this research (Vrišer, 1996a, b, 1997) have shown an unexpectedly great meiofaunal variability, trophic links of its seasonal cycles with pelagic and benthic microflora, as well as its fairly contradictory and diverse response to fortnightly hypoxic conditions in autumn 1994. As the results have also indicated a need for a long-term monitoring, the

investigations were repeated during the 1996-1999 period.

For financial reasons the research was somewhat limited although still carried out on the basis of similar methodology and with equal aims: to investigate seasonal dynamics of the total meiofauna and its main groups, to ascertain the impact of common and separate ecological factors of the physical environment on meiofauna in normal as well as in potentially hypoxic conditions, and to detect eventual signs of long-term oscillations or cycles.

### METHODS

The meiofauna was sampled with monthly frequency in the years 1996, 1997 and 1998 in the same area as during the 1992-1995 period, *i.e.* in the centre of the Gulf of Trieste, 25 m deep. As a result of the troubles with the research vessel and unfavourable weather conditions, no sampling was carried out from January to April 1996, in June 1997 and from November to December 1998; no data are therefore available for these months.

Surface sediment containing meiofauna was taken with gravity core sampler (Meischner & Rumohr, 1974), 5 cm deep, always with three replicates. Meiofauna was extracted from fixed samples (5% formalin) by sieving

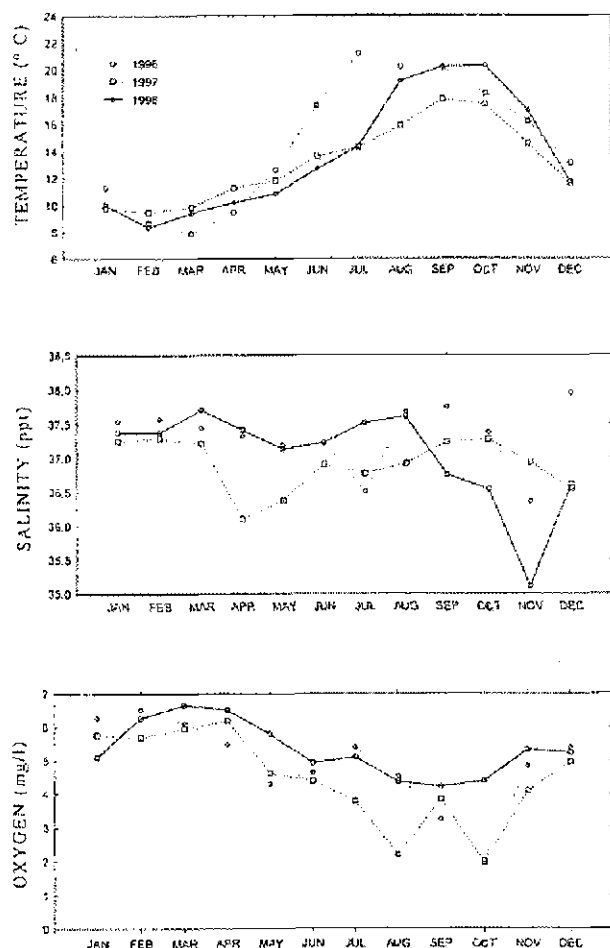


Fig. 1: Three year bottom - water layer dynamic (physical and chemical parameters) of the investigated area. Sl. 1: Triletna dinamika fizikalnih in kemijskih parametrov v pridnenem vodnem sloju raziskovanega območja.

and decantation (Wieser, 1960), identified to major taxa, counted and statistically processed (Statsoft, Statistica 5.0).

Meiobenthic sampling was accompanied by physical and chemical measurements (temperature, salinity, oxygen) and measurements of chlorophyll biomass (Chl *a*) of the bottom-water layer, carried out with electronic fine-scale profiler. A more detailed description of the used methods and a chart of the study area has been presented in one of the earlier papers (Vrišer, 1996a).

Due to drastically reduced financial support we were compelled to make use of gravity core sampler instead of carrying out manual sampling by SCUBA technique (as in the 1992-1995 period). Thus we had to give up the originally planned monthly measurements regarding the concentrations of benthic algae, sedimentation and the content of organic matter, and chemical characteristics of pore water of the sediment.

## RESULTS

### Ecological characteristics of the investigated area

The dynamics of the 3-year physical and chemical parameters is presented in figure 1. At the time of sampling, the seasonal oscillations of temperatures in the bottom-water layer ranged from the lowest winter values in February (8.5 - 9.5°C) to the highest summer values (18 - 21°C) with mean three-year temperature of 14.1°C.

The seasonal salinity oscillations showed expected raised values in the drier months of winter (December - February) and summer (July - September) and low values in the rainy months of spring (especially April 1997) and autumn (especially October 1996 and 1997). At the average salinity of 37.5‰, the measured extreme values ranged between 35.1 and 38‰.

Three-year movements of the oxygen content at the bottom showed a stable winter-spring period (January - April) of high values (90 - 100% saturation), a lower content (75%) in summer (June - July), and even lower content (70% or less) in early autumn when only 35% concentration of oxygen was measured in August 1997 and in October 1997 and 1998. The mentioned autumn minimums indeed neared hypoxic conditions, but the oxygen concentrations did not fall below the marginal value of 2 mg/l.

The sediment of the investigated station belongs, in geological terms, to silts situated between clayey silts of the coastal belt and silty sands of the open waters of the Gulf of Trieste. Granulometric structure: 65% silt, 25% clay, 10% sand (Ogorelec *et al.*, 1991).

Average amounts of the chlorophyll biomass (chlorophyll *a*) of the bottom pelagic microflora indicated periods of increased values in spring and autumn maximums: 1.9 mg/l in May and 4 mg/l in November. The latter was merely a statistical reflection of an extremely intensive algal bloom in autumn 1998.

### Meiofauna

Structural and quantitative characteristics of the investigated meiofauna, *i.e.* its taxonomic structure (main groups and its abundance) are given, in the form of a summary statistical survey, in table 1. The dominant group (75% relative density) was represented by Nematoda, followed by Harpacticoida (12%) and Polychaeta (7%), while the following 12 groups (Turbellaria, Gastro-poda, Bivalvia, Kinorhyncha, Acarina, Hydroidea, Ostracoda, Ophiuroidea, Amphipoda, Mysidacea, Cumacea, Decapoda) represented 6% of the entire meiofauna.

Seasonal dynamics of some more abundant meiofaunal groups are shown by diagrams of annual abundances (Fig. 2). The great majority of the groups showed low winter and high summer abundances. Characteristic

Tab. 1: Three year meiofauna abundance.

Tab. 1: Pregled triletnih abundančnih vrednosti meiofavne.

| TAXA            | Mean No./10 cm <sup>2</sup> | Rel. abundance % | Range No./10 cm <sup>2</sup> |      | SD of mean No. | SE of mean No. |
|-----------------|-----------------------------|------------------|------------------------------|------|----------------|----------------|
| total meiofauna | 478.96                      | 100.00           | 44                           | 1338 | 296.95         | 31.30          |
| Nematoda        | 361.29                      | 75.43            | 16                           | 1051 | 218.91         | 23.08          |
| Harpacticoida   | 57.19                       | 11.94            | 1                            | 237  | 93.95          | 5.69           |
| Polychaeta      | 35.09                       | 7.33             | 3                            | 114  | 25.15          | 2.65           |
| Turbellaria     | 10.63                       | 2.22             | 0                            | 49   | 9.50           | 1.00           |
| Gastropoda      | 4.53                        | 0.88             | 0                            | 5    | 1.07           | 0.11           |
| Bivalvia        | 4.20                        | 0.80             | 0                            | 37   | 7.15           | 0.75           |
| Kinorhyncha     | 2.77                        | 0.58             | 0                            | 21   | 4.42           | 0.47           |
| Acarina         | 0.50                        | 0.28             | 0                            | 3    | 0.52           | 0.05           |
| Hydrozoa        | 0.49                        | 0.22             | 0                            | 7    | 1.29           | 0.14           |
| Ostracoda       | 0.41                        | 0.11             | 0                            | 23   | 5.18           | 0.55           |
| Ophiurozoa      | 1.36                        | 0.07             | 0                            | 30   | 4.01           | 0.42           |
| Amphipoda       | 1.34                        | 0.04             | 0                            | 4    | 0.78           | 0.08           |
| Mysidacea       | 1.04                        | 0.00             | 0                            | 1    | 0.11           | 0.01           |
| Cumacea         | 1.03                        | 0.00             | 0                            | 1    | 9.48           | 1.00           |
| Decapoda        | 0.02                        | 0.00             | 0                            | 1    | 0.15           | 0.02           |

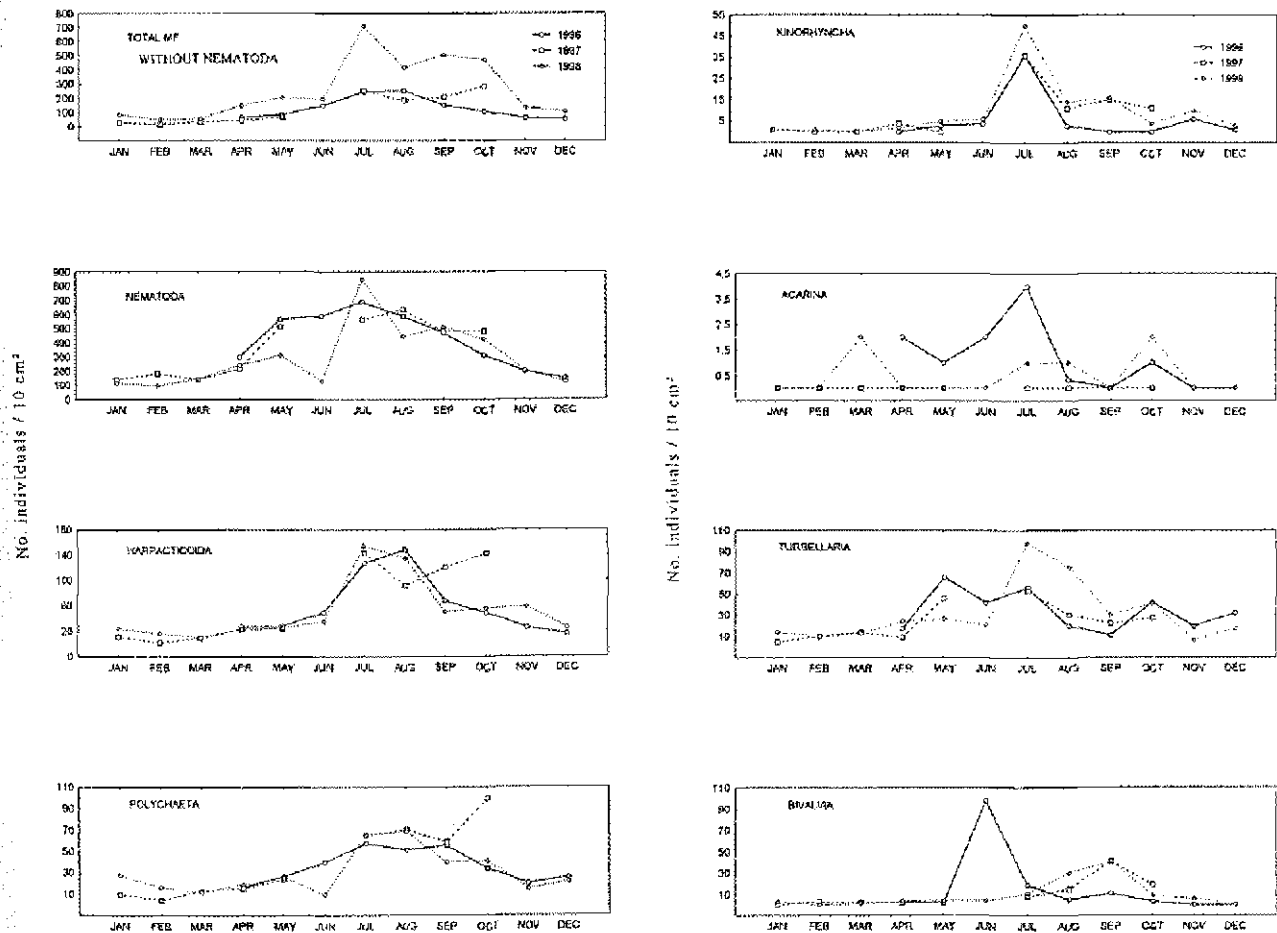


Fig. 2: Seasonal changes (1996, 97, 98) of some meiofaunal groups. Abundance as mean (No.ind./10cm<sup>2</sup>) or sum of 3 replicates (No.ind./30 cm<sup>2</sup>).

Sl. 2: Sezonske spremembe (1996, 97, 98) posameznih skupin meiofavne. Abundanca kot srednja vrednost (št.os./10cm<sup>2</sup>) ali vsota osebkov (št.os./30cm<sup>2</sup>) treh paralelk.

of the annual abundance cycle of the dominant Nematoda was a distinct summer peak (July), followed by somewhat weaker maximum in autumn (September). The winter Nematoda maximum lasted from December to March. Harpacticoida reached the summer maximum in July and August. This was followed by a decrease to the autumn stagnation (October, November), and this by an explicit winter-spring depression from December to April. Seasonal development of Polychaeta showed a summer increase in density with the peak in August (the few rare deviations can be assessed as atypical).

Meiofauna's long-term trends were monitored with an estimate of mean annual abundances for the 3-year 1996-1999 period (Fig. 3). In the entire meiofauna and in the first three leading groups the abundance was on the increase in this period. While a more distinct rise was noted in Nematoda and, consecutively, in the entire meiofauna in the 1997-1998 period, the mean annual abundance in Harpacticoida and Polychaeta was on the increase largely in 1996-1997.

Tab. 2: Pearson's correlation coefficients for meiofaunal taxon correlations with temperature, salinity, oxygen and phytoplankton (Chl a).

Tab. 2: Pearsonovi korelacijski koeficienti taksonomskih skupin meiofavne s temperaturo, slanostjo, kisikom in fitoplanktonom (Chl a).

| TAXA          | temperature        | salinity | oxygen             | chlorophyll a |
|---------------|--------------------|----------|--------------------|---------------|
| Meiofauna     | +0.66 <sup>x</sup> | -0.02    | -0.54 <sup>x</sup> | -0.16         |
| Nematoda      | +0.61 <sup>x</sup> | -0.05    | -0.50 <sup>x</sup> | -0.18         |
| Harpacticoida | +0.66              | +0.00    | -0.55 <sup>x</sup> | -0.01         |
| Polychaeta    | +0.65 <sup>x</sup> | +0.07    | -0.69 <sup>x</sup> | -0.20         |
| Turbellaria   | +0.47 <sup>x</sup> | -0.05    | -0.24              | -0.14         |
| Gastropoda    | +0.55 <sup>x</sup> | +0.16    | -0.20              | -0.16         |
| Bivalvia      | +0.53 <sup>x</sup> | +0.20    | -0.31              | -0.08         |
| Kinorhyncha   | +0.42 <sup>x</sup> | -0.07    | -0.24              | -0.02         |
| Acarina       | +0.35              | +0.23    | +0.06              |               |
| Hydroidea     | +0.23              | +0.14    | +0.15              | -0.08         |
| Ostracoda     | +0.33              | -0.07    | -0.01              | -0.07         |
| Ophiuroidea   | +0.34              | +0.03    | -0.47 <sup>x</sup> | -0.13         |
| Amphipoda     | +0.51 <sup>x</sup> | +0.11    | -0.25              | +0.21         |
| Mysidacea     | +0.15              | +0.05    | +0.01              |               |
| Cumacea       | +0.30              | +0.23    | -0.24              | -0.05         |
| Decapoda      | +0.27              | +0.02    | -0.44 <sup>x</sup> | +0.13         |

<sup>x</sup> sign. at p < 0.05

The relation between the selected ecological factors (temperature, salinity, oxygen, chlorophyll a) and meiofauna was checked with Pearson's correlation coefficient (Tab. 2). The coefficients show predominantly positive correlation of the entire meiofauna and its groups with the temperature and salinity, while the correlation with the chlorophyll biomass and oxygen content is negative.

The mean 3-year course of the seasonal cycle of the bottom plankton microflora (microphytopelagic biomass

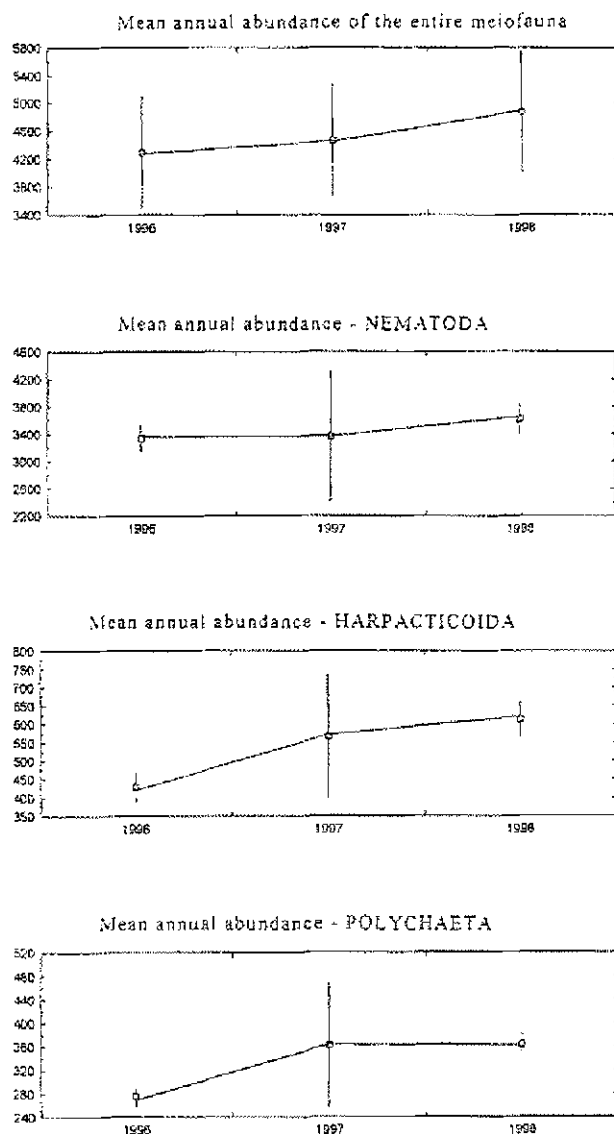


Fig. 3: Yearly mean abundances (+SE) of total meiofauna and some dominant groups.

Sl. 3: Srednje letne abundance (+SE) celotne meiofavne in nekaj vodilnih skupin.

- chlorophyll a) and meiofauna is shown in figure 4. The 1996-1999 Nematoda abundance curve is, very much as noticed during the earlier investigations in 1992-1995, to a certain extent a repetition of the changes in the chlorophyll biomass, this time with even greater (2-month) lag. Thus the Nematoda follow algal blooms in March and May with successive maximums in May and July, while the smaller algal increase in August is probably reflected in somewhat slowed down decrease in the Nematoda abundance in September and October. At the end of the research period in December the meiofauna did not yet respond to the exceptionally intense autumn phytoplankton blooms in November 1998. Har-

pacticoida reached the summer maximum, the same as Nematoda, in July, two months after algal blooms (in May), while in the sparse Polychaeta the seasonal lag seems less distinct.

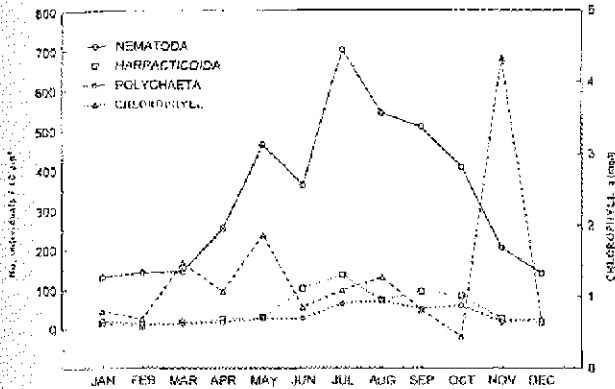


Fig. 4: Three year mean seasonal dynamic of dominant meiofaunal groups and phytoplankton (Chl a).

Sl. 4: Triletna srednja sezonska dinamika treh vodilnih skupin meiofavne in fitoplanktona (Chl a).

## DISCUSSION

The results of the investigations carried out from 1996 to 1999 on seasonal and long-term meiofaunal variations in central part of the Gulf of Trieste showed fairly similar qualitative relations, seasonal cycles and the impacts of the ecological factors as some previously investigations in the same place in 1992-1995. As quantitative changes (by a third lower abundances) manifested themselves for already mentioned methodological reasons (sampling with gravity core instead of by diver), no direct comparisons between absolute abundances of both periods are possible.

Meiofaunal seasonality more or less confirmed the previously obtained characteristics, especially as far as most abundant groups are concerned, and less in respect of rarer species, where some greater "anomalous" deviations from seasonal pattern were noted. This problem, however, could be solved only with a selective sampling of substantially larger series of samples.

In Nematoda, Harpacticoida and Polychaeta their distinct summer culmination (particularly in July) follows the spring phytoplankton blooms (in May). In Nematoda a slight autumn rise is perceived after the July peak, which is also notable in Harpacticoida and especially in Polychaeta - in 1997, for example, very distinctly, and in other years very scantily. The three-year observations thus confirmed and more or less clarified the picture of seasonal changes in the investigated groups of the studied fauna.

The response of meiofauna to some ecological factors was similar to that in 1992-1995: positive Pearson's

correlation coefficients with temperature and salinity, and negative coefficients with the oxygen content and pelagic chlorophyll. A special attention as far as the ecological factors are concerned deserves to be given particularly to plankton chlorophyll, especially in its relation to meiofauna. The already mentioned trophic links between meiofauna and primary producers (Vrišer, 1996) have been described by many studies (Blanshard, 1990; Fleeger *et al.*, 1989; Grant & Schwinghamer, 1987; Montagna *et al.*, 1995; Rudnick *et al.*, 1985).

In comparison with a one-month lag of meiofauna behind seasonal blooming cycle of benthic one-celled algae (as shown by a few years old data), the processes of sedimentation, accumulation and decomposition from one-celled pelagic algae into bacterial agglomerations and bottom organic detritus are probably responsible for a similar but greater two-month lag of the meiofaunal cycle behind the rhythm of phytoplankton. To confirm this thesis, a carefully planned and distinctly lasting study of simultaneous monitoring of environmental phytoplanktonic, phytobenthic and meiofaunistic components would be needed.

As no true hypoxic conditions occurred in the research period, this phenomenon could not be investigated anew. The oxygen level was therefore not critical even for hypoxically sensitive macrobenthos. From our earlier investigations as well as from literature (Dauer & Alden, 1995), a substantially greater meiobenthos' ability to survive in hypoxic conditions is known.

The seemingly illogical meiofauna's negative correlation with oxygen and phytoplankton chlorophyll is explainable with meiofauna's phase or seasonal lag: the curves of meiofauna, especially Nematoda, and of both ecological factors are almost in alternation!

We interpret our results that the seasonal cycles of meiofauna in the investigated area are directly controlled particularly by temperature, by oxygen more or less periodically in stressful hypoxic conditions, and indirectly and thus behind time by phytoplankton through complex processes of sedimentation and decomposition in direction from pelagic to benthic trophic levels, most probably in combination with other mechanisms, such as competition and predation.

Although the changed sampling methodology prevent us, as already said, to make direct comparisons with earlier abundances, the yearly mean values of the key groups and the whole show a 3-year rising trend in the meiofauna's abundance. This trend upwards indicate, in connection with the 3-year trend of decline established during earlier investigations, a first possible trace of long-term oscillations hiding behind the "curtain" of seasonal dynamics. For a clearer picture, at least a 10-year continued observations would be necessary.

For this very reason and for the sake of other already mentioned open questions, we shall resume the investigations in this particular sphere.

## SEZONSKE IN VEČLETNE SPREMEMBE MEIOFAVNE V OKOLJU POGOSTO PRIZADETIM S HIPOKSIJAMI V OSREDNJEM DELU TRŽAŠKEGA ZALIVA

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## POVZETEK

V triletnem obdobju 1996-99 smo z mesečno frekvenco raziskovali meiofavno v centru Tržaškega zaliva. Rezultati študije, ki je nadaljevanje starejših raziskav iz let 1992-95, so pokazali podobno sezonsko dinamiko in vpliv nekaterih ekoloških faktorjev na meiofavno. Prevladovali so Nematoda s 75% relativne abundance, sledili so Harpacticoida (12%) in Polychaeta (7%), preostalih 12 skupin je predstavljalo skupno 6%. Raziskave so nekoliko izostrile in dopolnile dosedanje poznavanje sezonskih sprememb meiobentosa, ki pri vodilnih skupinah kaže izrazito povišane poletne gostote in manjši jesenski maksimum. Opazili smo dvomesečni časovni zamik sezonskega cikla meiofavne za letnim ciklom fitoplanktona. Časovna razlika morda ustreza procesom sedimentacije in razgradnje fitoplanktona v organski detrit sedimenta kot pomembnega prehranjevalnega vira meiofavne. V raziskovanem obdobju ni bilo hipoksičnih razmer. Srednja enoletna povprečja celotne meiofavne in vodilnih skupin kažejo triletni trend naraščanja abundanc in tako sledijo triletnemu trendu upadanja, vidnega iz starejših opazovanj.

**Ključne besede:** sezonska dinamika, bentoška meiofavna, Tržaški zaliv

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## MEIOFAVNA STRUNJANSKEGA ZALIVA 18 LET POZNEJE: PONOVLJENA RAZISKAVA

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### IZVLEČEK

*Prispevek obravnava raziskavo abundančnih značilnosti meiofavne vzdolž globinskega profila 5 postaj od 1 do 15 m, ki smo jo po 18 letih (1979-1997) ponovili v Strunjanskem zalivu. Rezultati potrjujejo starejše podatke o obstoju dveh asociacij meiofavne - prva je vezana na pas morskih trav, druga (globlja) pa na golo sedimentno dno.*

**Ključne besede:** meiofavna, ponovljena raziskava, Strunjanski zaliv

### UVOD

V okviru raziskav meiofavne slovenskega obalnega pasu smo v letih 1978/79 s pomočjo vzorčevanja poletnih in zimskih globinskih profilov raziskovali notranjost Strunjanskega, Piranskega in Koprškega zaliva. Raziskovanja so osvetlila vpliv abiotskih ekoloških faktorjev na združbe meiofavne, predvsem vpliv fizikalnega in kemičnega značaja sedimenta v čistem in onesnaženem okolju in vpliv globine ter vpliv valovanja (Vrišer, 1982, 1983, 1986). Strunjanski in Piranski zaliv sta nam pri tem rabila kot primerjava onesnaženemu Koprskemu zalivu.

Minuli dve desetletji tudi Strunjanskemu zalivu v ekološkem pogledu nista povsem prizanesli. Občutno povečanje turistične oz. kopalniške infrastrukture vse bolj urbanega zaledja in postavitve obsežnih školjčnih nasadov sta le dva izmed dejavnikov, ki so domnevno tako ali drugače dodatno obremenili to morsko okolje. Naša raziskovanja meiofavne so se medtem premaknila v smeri študija sezonskih in dolgoletnih sprememb in tako se je ponudila priložnost, da s pozicije večje časovne distance ponovimo vsaj enega od omenjenih globinskih presekov in tako ugotovimo obseg in vrsto morebitnih sprememb v združbah meiofavne. Ponovljeni globinski presek meiofavne Strunjanskega zaliva, prvo vzorčevanje je bilo marca 1979, smo opravili po 18 letih marca 1997 na natanko istih lokacijah (globinskih postajah 1, 2,5, 5, 10, 15 m) in s povsem enako metodiko odvzema vzorcev (gravitacijska sonda, 3 paralelke, površinski sediment 10 cm<sup>3</sup>, 5 cm globoko) in standardne ekstrakcije favne.

Pričujoči prikaz je preliminarnega značaja, saj bo obstoječe rezultate v drugi fazi nujno dopolniti še z

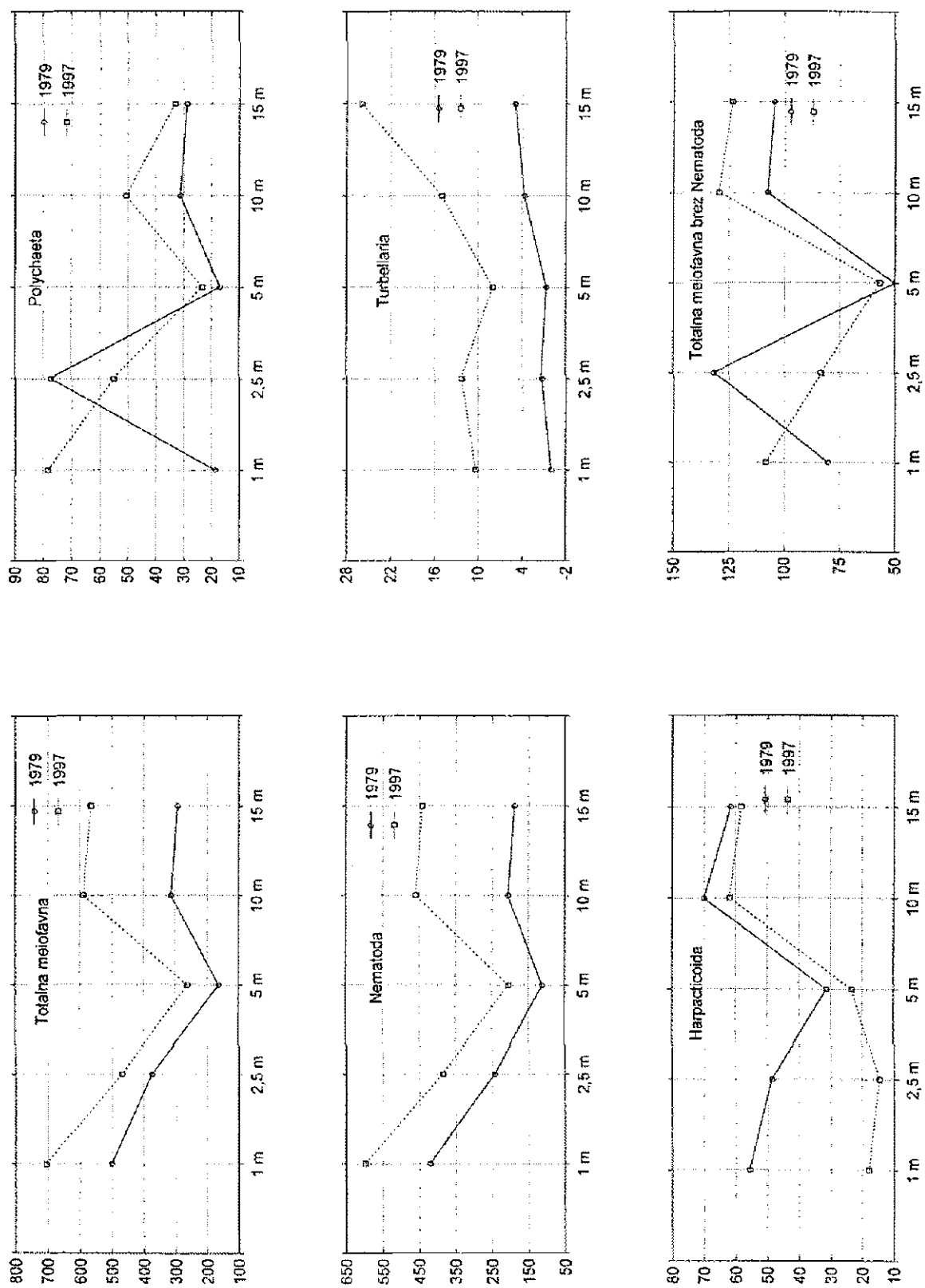
dotatnimi ekološkimi raziskavami abiotskega okolja, tako kot v letu 1979, vendar že na tej stopnji daje nekaj zanimivih zaključkov, a tudi zastavlja nova vprašanja.

### EKOLOŠKE ZNAČILNOSTI STRUNJANSKEGA ZALIVA

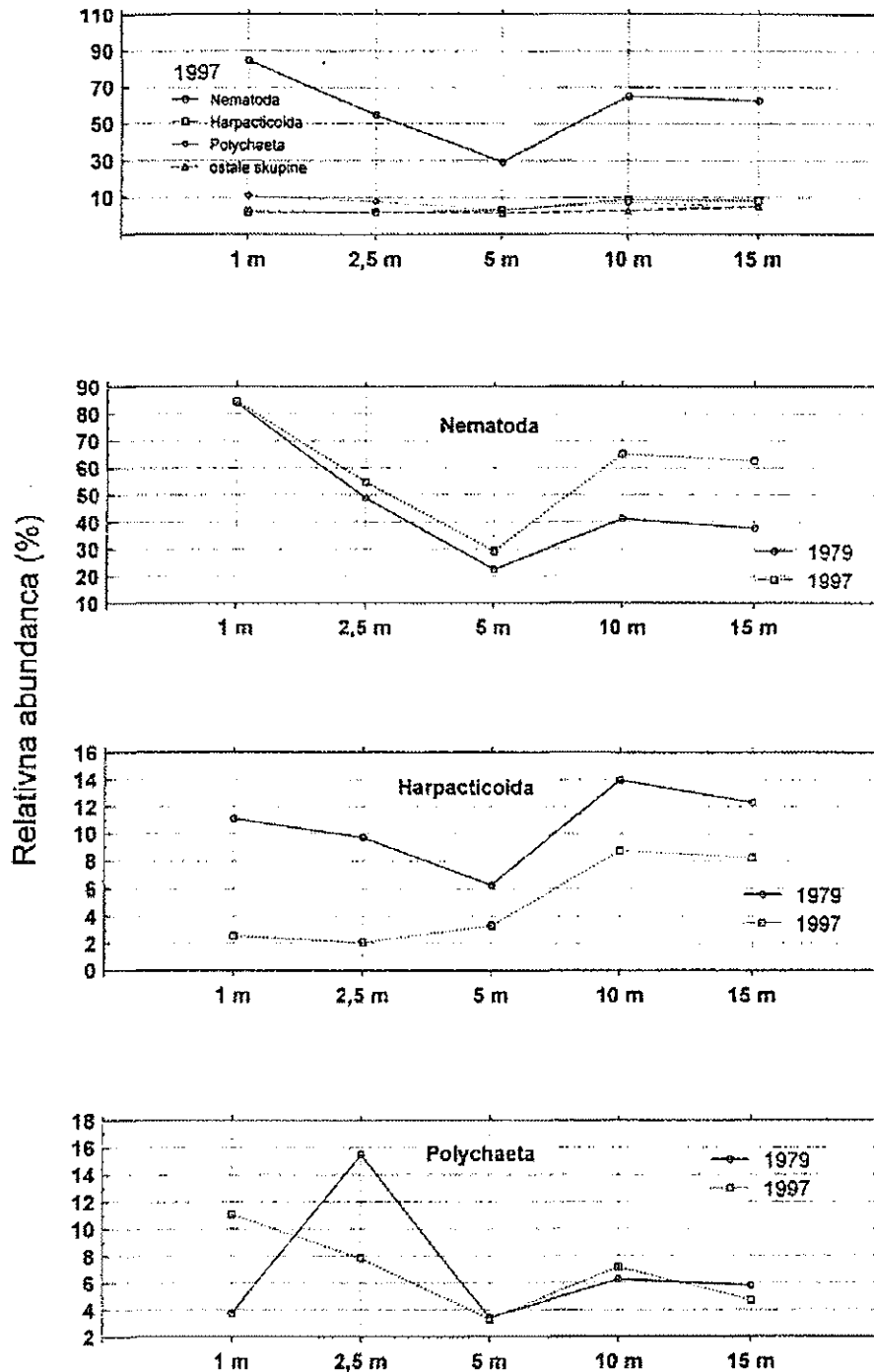
Strunjanski zaliv sodi med manjše zalive in je po vsej svoji polovici na široko odprt proti severozahodu. Njegova geografska lega, a tudi vrsta osnovnih ekoloških značilnosti ga uvrščajo med dve skrajnosti naše obale, ki jih ponazarja plitva, zamuljena notranjost večjih zalivov (kot sta Koprski in Piranski) na eni strani, in med izpostavljene, odprte dele obale na drugi strani. Po geološki zrnavosti (granulaciji) sodi sediment zaliva med glinaste melje, kjer delež gline narašča z globino, del plitvega (1-2 m) obrežnega pasu pa je zaradi valovanja bolj izpran in v razponu peščenih meljev.

Fizikalne in kemijske značilnosti (temperatura, slanost, kisik, hranilne soli) se v glavnem ujemajo s povprečnimi vrednostmi Tržaškega zaliva. O manjšem vplivu zaslajevanja zaradi edinega vodotoka (Strunjanskega potoka) lahko govorimo le občasno in je zanemarljivega obsega.

Plitvejši del raziskovanega profila, neposredno pod bibavično cono od 1 do 7 m globine, obvladuje makrobentoška združba sklenjenih travnikov morskih cvetic *Cymodocea nodosa* z značilno notranjo in površinsko favno sedimenta, z redkimi algami, na listih trav pa z obrastjo številnih epifitskih vrst. Globlje od osmih metrov, kjer morske trave izginejo, se pričinja golo mehko sedimentno dno za katero so značilni iglokožci, vrsta polžev in školjk in številni črvi mnogocetinci.



Sl. 1: Abundanca (št. os./10 cm<sup>2</sup>) celotne meiofaune in njenih vodilnih skupin v Strunjskem zalivu vzdolž globinskega profila 5 postaj v letih 1979 in 1997.  
 Fig. 1: Abundance (No. ind./10 cm<sup>2</sup>) of the total meiofauna and its leading groups in the Bay of Strunjan along 5 stations transect in 1979 and 1997.



Sl. 2. Relativna abundanca (%) vodilnih skupin meiofavne vzdolž globinskega profila 5 postaj v Strunjanskem zalivu v letih 1979 in 1997.

Fig. 2. Relative abundance (%) of the meiofaunal leading groups along 5 stations transect in the Bay of Strunjan in 1979 and 1997.

Raziskava globinskega profila je pred osemnajstimi leti nakazala, da tudi meiofavna najverjetneje odseva obe bentoški zonaciji travnikov in golega dna. Abundance celotne meiofavne in večine skupin vzdolž pro-

fila, predvsem pa diverzitetna analiza harpaktikoidnih kopepodov (Copepoda, Harpacticoida) so dale slutiti, da je sicer še mogoče govoriti o eni združbi meiofavne, a z dvema verjetnima asociacijama: s priobalno asociacijo

višje gostote in diverzitet, vezane na morske travnike, bogatejše z organskim detritom, in z globinsko asociacijo globlje od travnikov. Meja med njima se je v abundančno dinamiko globinskega preseka sicer zarisala z daleč najnižjo vrednostjo pri 5 m, toda najnižja diverzitet kopepodov je bila pri 10 metrih globine.

### REZULTATI IN ZAKLJUČKI

Ponovitev raziskav globinskega preseka je pokazala zelo podobne, v povprečju le za četrtno višje vrednosti celotne (totalne) meiofavne kot pred 18 leti. Tudi dinamika oz. abundančne spremembe z globino so bile na ravni celotne meiofavne skoraj enake kot tedaj: enakomerno upadanje gostote do postaje 5 m, nato znova porast in ustalitev gostote pri 10 in 15 m. Manjše razlike med obema vzorčevanjema so se pokazale bolj pri globinski odzivnosti posameznih vodilnih skupin. Tako so novejšje gostote nematodov (Nematoda) in turbelarijev (Turbellaria) za približno tretjino višje, v globljem zunanem delu zaliva pa celo izrazito - do trikrat - višje kot pred leti. Obratno pa so bile sedanje abundance pri harpaktikoidih (Harpacticoida) in deloma tudi pri polihetih (Polychaeta) nižje kot nekoč, še posebno v plitvem delu profila (1-5 m) kjer so bile za nekajkrat nižje. Omenjene značilnosti odsevajo tudi krivulje relativnih abundanc. Relativni delež (%) nematodov je v l. 1997 vzdolž preseka nihal od 30 do 90%, posamezni

deleži kopepodov, polihetov in vseh preostalih skupin skupaj so na skoraj vseh postajah znašali blizu 10%.

Abundančno dinamiko v absolutnih in relativnih (%) vrednostih vzdolž globinskega preseka obeh vzorčevanj (1979, 1997) prikazujeta sliki 1 in 2.

Ponovljeno vzorčevanje je v celoti potrdilo starejšo razdelitev obalne združbe meiofavne na dve biocenot-ski podoenoti, t.j. na asociacijo meiofavne morskega travnika (postaje na globinah 1-5 m) in na asociacijo golega sedimentnega dna (postaji na globinah 10 in 15 m) z vmesnim prehodom nizke favnistične gostote (postaja na globini 5 m), kar pred dvema desetletjema ni bilo tako jasno vidno.

Izrazito nižje gostote, ki jih opazimo pri kopepodih in polihetih na plitvih postajah, so lahko odsev bodisi večje ekološke variabilnosti plitvega, terestričnim vplivom izpostavljenega dela zaliva (Boero, 1994; Gray & Christie, 1983), potencialno pa tudi trajno spreminjenih, za zdaj nam neznanih dejavnikov.

Vidno povišanje abundanc nematodov in turbelarijev v globljem delu zaliva (če ga primerjamo s starimi podatki) je brez vrste dopolnilnih raziskav še teže razložljivo. Postavitev obsežnih školjčič v zalivu v zadnjih dvajsetih letih in posledično verjetna sedimentacija školjčnega fecesa in z njo povezana spremenjena bilanca organske materije v sedimentu nakazujejo iskanje odgovora v tej smeri.

## MEIOFAUNA IN THE BAY OF STRUNJAN 18 YEARS AFTER: A REPEATED INVESTIGATION

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### SUMMARY

*To establish potential long-term changes, a meiofaunal sampling along a transect of 5 stations (1, 2.5, 5, 10, 15 m) was repeated 18 years (1979, 1997) after the first meiobenthic study in the Bay of Strunjan. Recent results show similar structural and quantitative characteristics of the meiofauna community as two decades ago. Two distinctive associations become evident: the first belongs to the shallower seagrass meadows between 1 and 7 m in depth, the second to the deeper area below the seagrass belt. Some local abundance differences among meiofaunal groups along the depth transect are not explainable because of deficient environmental data.*

**Key words:** meiofauna, repeated investigation, Bay of Strunjan

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## VNOS TUJERODNIH ORGANIZMOV V SEVERNEM JADRANU IN UPRAVLJANJE BALASTNIH VOD

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### IZVLEČEK

*V članku opozarjamo na obstoječo nevarnost vnosa tujerodnih organizmov z balastnimi vodami in potrebo po uvedbi nadzora. Delo temelji na pregledu strokovne literature kot tudi na utrjevanju stanja pri odgovornih organizacijah. Obenem podaja smernice za potrebne ukrepe na tem področju.*

**Ključne besede:** balastne vode, tujerodne vrste, upravljanje, slovensko morje, severni Jadran

#### UVOD

Zgodovina pomorstva je polna legend in skoraj neverjetnih zgodb o junaštvi ljudi, ki so z lesenimi galejami obpluli prostrani svet. Z odkritji novih celin, vzpostavitev stikov z drugačnimi kulturami in kolonializacijo se je pričelo tudi medcelinsko trgovanje z najrazličnejšim blagom. S prevozom različnih tovorov so začeli prenašati tudi razne vrste živali in rastlin, ki so se tako znašle v novem okolju. Nekatere vrste, na primer pižmovka, so se v tem okolju ustalile, ne da bi povzročile kako škodo. Poznamo pa tudi primere s škodljivimi posledicami, npr. koloradskega hrošča.

Vse večja medcelinska trgovina je narekovala graditev večjih in zmogljivejših tovornih ladij. Kadar ladja pluje brez tovara, potrebuje dodatno obtežitev, ki ji zagotavlja ustrezne razmere za varno plovbo. Stvari, uporabljene v ta namen, imenujemo balast. Nekdaj so kot balast uporabljali pesek, kamenje ipd., ob koncu 19. stoletja pa so v ta namen začeli v posebne (balastne) tanke polniti (balastno) vodo.

Masovni prevoz raznovrstnega blaga med celinami lahko s svojimi tehničnimi in tehnološkimi lastnostmi zadovolji le pomorski promet. Ta danes opravlja več kot 90% vsega prekmorskega prevoza blaga (IMO, 1998a). Vse večja globalizacija trgovine pa kaže, da bo pomorski promet v prihodnosti ohranil oz. še povečeval svojo vlogo.

Po nekaterih ocenah tako vsako leto potuje po svetu, skupaj z ladjami, okoli 10 bilijonov ton balastne vode (IMO, 1998a). Planktonske raziskave so pokazale, da lahko razne vrste bakterij, rastlin in živali preživijo v

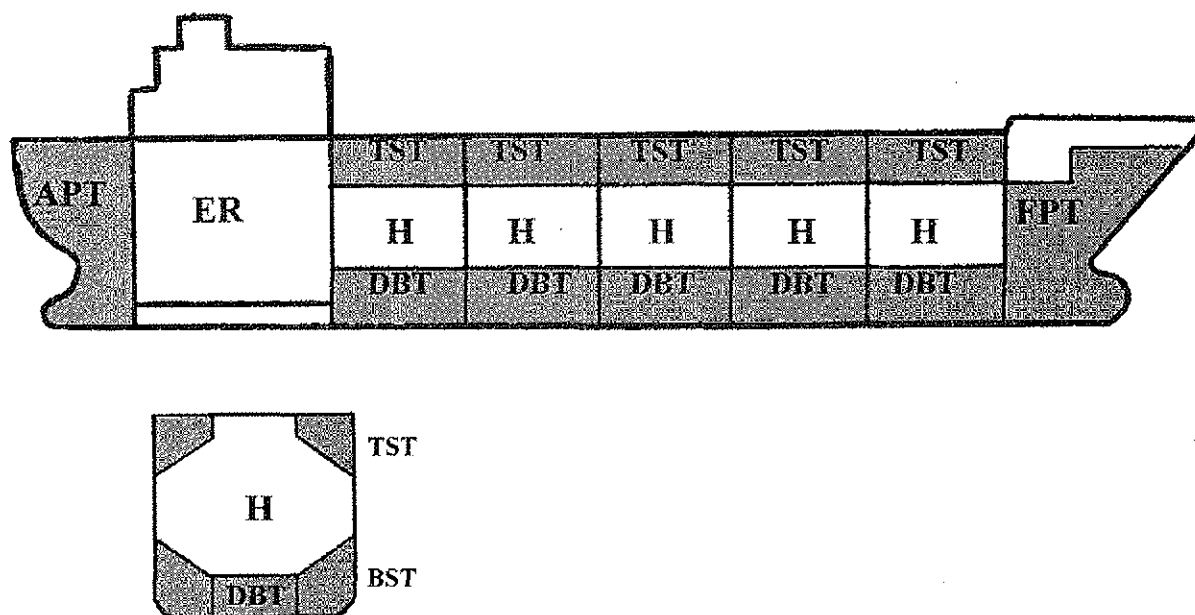
balastni vodi in sedimentu tudi po nekaj mesecev (IMO, 1997). Tako obstaja nevarnost, da balastna voda, napolnjena na enem koncu sveta in nato izpuščena na drugem koncu, vsebuje škodljive tujerodne organizme. Po nekaterih ocenah se z balastnimi vodami prenese okrog 3000 različnih vrst tujerodnih organizmov na dan (IMO, 1998a).

S tem člankom želim predvsem opozoriti na obstoječo nevarnost za okolje in ljudi, kot posledico prenašanja tujerodnih morskih organizmov in patogenov z balastnimi vodami, in hkrati prikazati možne smernice za zmanjšanje te nevarnosti v slovenskih vodah.

#### METODE IN MATERIALI

Delo temelji na poglobljenem pregledu dokumentov, člankov in znanstvene literature strokovnjakov, ki delujejo v komiteju MEPC (Marine Environment Protection Committee) v okviru Mednarodne pomorske organizacije IMO (International Maritime Organization) in drugih mednarodnih organizacij.

Izdelavo tega dela sem zasnoval na presoji problemov in nevarnosti kot posledico morebitnega vnosa škodljivih tujerodnih organizmov v slovenske obalne vode. Za lažje razumevanje sem opisal in prikazal pomen balastnih vod za varno plovbo trgovske ladje, definiral tujerodne vrste in njihove vplive, navedel poznane primere vnosov z manj ali bolj škodljivimi posledicami. Predstavil sem tudi stanje s pravnega vidika in možne načine upravljanja balastnih vod ter nadzor, da bi se zmanjšale nevarnosti vnosa. Za ugotovitev stanja in smernic v Sloveniji sem opravil po-



H - skladišče za tovor (cargo hold)  
ER - strojnica (engine room)

Sl. 1: Prikaz razporeditve balastnih tankov na ladji za prevoz sipkih tovorov (Risba: M. David).

Fig. 1: Ballast tanks arrangement in bulk carrier ship (Drawing: M. David).

govore na Upravi Republike Slovenije za pomorstvo in Morski biološki postaji v Piranu (MBP).

## REZULTATI IN RAZPRAVA

### Balastne vode

Trgovske ladje so zgrajene za prevoz raznovrstnega blaga po morju ali notranjih plovnih poteh. Ko prazna ladja pluje do pristanišča, kjer bo naložila tovor, potrebuje balast, ki ji zagotovi: ustrezen ugrez zaradi prijema ladijskega pogonskega vijaka, ustrezen trim, potrebno prečno in vzdolžno stabilnost ter s tem plovno sposobnost.

Definicija IMO pravi: "Balastna voda pomeni vodo in suspendirane snovi, naložene na ladjo zaradi uravnavanja trima, ugreza, stabilnosti ali napetosti ladje" (IMO, 1999a, b, c, d).

Vrste ladij, kot so kontejnerske, za generalne tovore ali RO-RO ladje (trajekti, za prevoz avtomobilov...), potrebujejo le majhne količine balastnih vod. Razne vrste ladij - za prevoz sipkih tovorov, rud, utekočinjenih plinov, tankerji in podobne - pa potrebujejo veliko večje količine balastne vode. To je navadno okrog 10.000 ton, lahko pa celo prek 100.000 ton na ladjo.

Balastno vodo napolnijo v posebej za to namenjene tanke, to je balastne tanke. Ti so najpogosteje nameščeni v dvodnu, ti. tanki dvodna (DBT - double bottom tanks), levo in desno ob straneh dvodna, ti. stranski

tanki dvodna (BST - bottom side tanks), na premcu, ti. premčeni tank (FPT - fore-peak tank), na krmi, ti. krmni tank (APT - after-peak tank), levo in desno pod glavno palubo ti. višinski tanki (TST - topside tanks), obstajajo pa še nekatere druge vrste, npr. stranski (ST - side tanks), sredinski... (sl. 1). Po dolžini ladje so tanki dvodna, stranski in višinski tanki razmejeni kot skladišča tovora.

### Tujerodne vrste

Tujerodne vrste (NIS - nonindigenous species) so katerekoli vrste ali druge za življenje sposobne biološke snovi, vnešene v neki ekosistem zunaj njihovih zgodovinskih meja, vstevši vsak organizem, ki je bil prenesen iz ene dežele v drugo (ANS Task Force, 1999).

Škodljive vodne vrste (ANS - aquatic nuisance species) so tujerodne vrste, ki ogrožajo: raznovrstnost (diverziteto) avtohtonih vrst, množičnost avtohtonih vrst, ekološko stabilnost voda in trgovsko, kmetijsko, vodnogospodarsko ali rekreacijsko dejavnost, odvisno od teh vod, ter vplivajo na zdravje ljudi (ANS Task Force, 1999).

Pojavljajo se v notranjih vodah, izlivih rek in morskih vodah, njihove škodljive vplive pa lahko razdelimo v tri skupine:

a.) vplivi na okolje: plenilstvo, parazitizem, konkurenca, vnos novih patogenov, genetika in spremenjanje naravnega okolja rastlin ali živali (ANS Task Force, 1999);



b.) ekonomske škode v: industrijski potrošnji vod, mestni vodooskrbi, nuklearnih energetskih napravah, trgovskem in športnem ribolovu ter raznih vodnih sportih;

c.) skrbi javnega zdravstva: nevarnost kolere in nevarnost zastrupitve.

Definicija IMO pravi: "Škodljivi morski organizmi in patogeni pomeni morske organizme in patogene ali njihove dele, ki vneseni v morje, estuarije ali sladkovodne poti lahko pomenijo nevarnost za človekovo zdravje, poškodujejo žive vire, morská bitja in druge naravne dobrine, škodijo biotski raznovrstnosti ali drugače vplivajo na zakonito izkoriščanje morja" (IMO, 1999a, b, c, d).

#### Primeri vnosa škodljivih tujerodnih organizmov z balastnimi vodami po svetu

Na svetu je znano veliko število primerov vnosa kot tudi negativnih posledic, vendar za predstavitev problema navajam le tri značilne:

- Vnos evropske zebaste školjke (*Dreissena polymorpha*) v Velika jezera (ZDA), kar naj bi se bilo po predvidevanjih znanstvenikov zgodilo nekje leta 1986 (Briand, 1994). Zebasto školjko so prvič opazili 1988. leta v jezerih Earie in St. Clair pri Detroitu (Michigan). Izvira iz Črnega, Azovskega in Kaspijskega morja. Ima veliko sposobnost oprijema na razne vrste površin. Navadno se naseljuje v kolonijah, kjer populacija šteje od 5 do 30 tisoč primerkov na m<sup>2</sup>, odvisno od ugodnosti razmer. Na stotine milijonov zebastih školjk je danes naseljenih na dnu jezer in rek, po obalnih skalah, boah in plavajočih objektih. Ker se prehranjujejo s filtriranjem

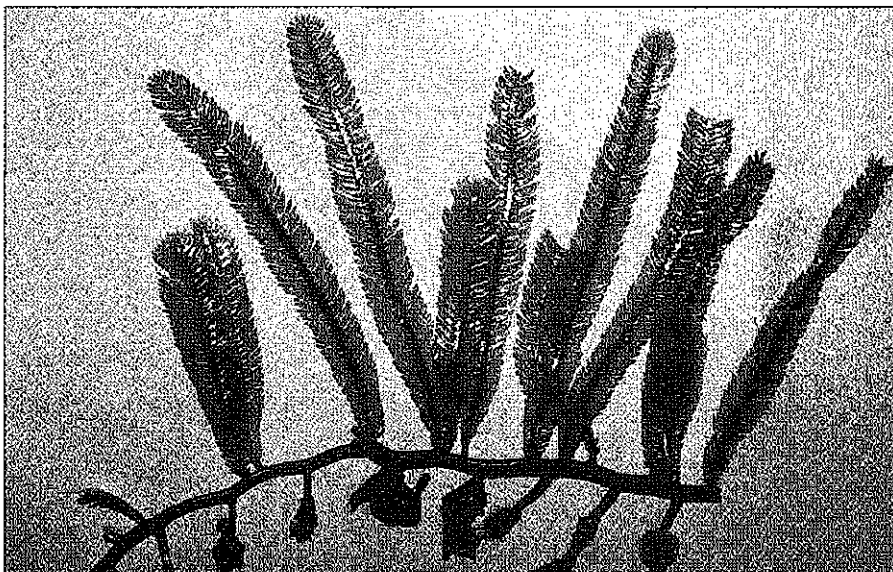
vode, porabijo večino mikroorganizmov, ki so navadno hrana tudi drugim vodnim živalim. Poleg tega prekrivajo skalnate površine, kjer navadno ribe ležejo jajčeca. Prav tako so velik problem za hidroelektrarne, komercialni in športni ribolov ter turizem. Skupno škodo, ki jo povzroča zebasta školjka v ZDA, ocenjujejo na 5 milijard dolarjev na leto (Briand, 1994).

- Vnos vzhodno-ameriške rebrače *Mnemiopsis leidyi* v Črno in Azovsko morje, do katerega naj bi bilo prišlo ob koncu 1980-ih. V okolju brez ustreznega plenilca je prišlo do eksplozivne rasti vrste. Prehranjuje se z zooplanktonom, ki je hrana mladih ribic, ter z ribjimi jajčeci. To je povzročilo drastični upad ribjih mladici inčunov in papalin, s tem pa tudi veliko gospodarsko škodo za črnomorske države (Briand, 1994; GESAMP, 1997).

- Poznan je tudi primer, ko so bila ogrožena številna človeška življenja z vnosom povzročitelja kolere v obalne vode ZDA. To se je zgodilo leta 1991, ko so povzročitelja kolere odkrili v balastnih vodah ladje v pristanišču Mobile v Mehiškem zalivu, Alabama - ZDA (ANS Task Force, 1999).

#### Primeri pojavljanja tujerodnih organizmov v severnem Jadranu

V Sredozemskem morju se čedalje pogosteje pojavljajo tujerodne vrste vodnih organizmov, ki v večini primerov ne povzročijo hujših posledic v novem okolju. V severnem Jadranu so opazili pojavljanje 12 tujerodnih vrst mehkužcev, to je 3 vrst polžev in 9 vrst školjk (De Min & Vio, 1998). Sedem od teh vrst (*Rapana venosa*, *Bursatella leachi*, *Scapharca inaequivalvis*, *Musculista*



Sl. 2: Alga *Caulerpa taxifolia*, najdena leta 1998 v zalivu Malinska (Foto: T. Makovec).

Fig. 2: Alga *Caulerpa taxifolia* found in the Bay of Malinska in 1998 (Photo: T. Makovec).

*senhousia*, *Xenostrobus securis*, *Crassostrea gigas* in *Tapes philippinarum*) se je v novem območju že ustalilo, druge (*Strombus decorus*, *Brachidontes pharaonis*, *Perna picta*, *Pinctada radiata* in *Saccostrea commercialis*) pa naj bi bile naključne vrste (De Min & Vio, 1998). Te vrste se lahko širijo po naravni poti skozi Gibraltarsko ožino in Sueški prekop (ti. lesepske selivke - po Ferdinandu Lessepsu), lahko pa tudi zaradi človeških dejavnosti. Ko govorimo o človeških dejavnostih, so mišljeni primeri vnosa z balastnimi vodami, kot obrast na trupu ladje, z vnosom mladice tujerodnih vrst v gojiščih morskih organizmov ali pa kot posledica naraščanja števila tropskih morskih akvarijev, od koder lahko osebkii pobegnejo (De Min & Vio, 1998).

Tako je prišlo do "pobega" tropske alge *Caulerpa taxifolia* iz monaškega akvarija (Nolan, 1994), kar naj bi se bilo zgodilo med njegovim čiščenjem. Odtlej se je ta alga razširila po sredozemskih obalah Španije, Francije, Monaka, po vzhodni in zahodni obali Italije, najdemo pa jo tudi že v vzhodnem Jadranu, kjer so jo naj-severneje opazili v zalivu Malinska na otoku Krku. Gre za konkurenčno vrsto samoniklim algam in njihovi obrasti, ki jih postopoma izpodriva (Petrovčič, 1999).

### Pravni aspekti

Problematiko onesnaževanja morja z ladjmi v svetovnem merilu ureja konvencija MARPOL 73/78 iz leta 1973 in dopolnili iz leta 1978 (IMO, 1978). Vsebuje 6 aneksov. Prvotno so jih sprejeli 5, ki urejajo pa problematiko onesnaževanja z zaoljenimi vodami, nevarnimi tekočimi snovmi, embaliranimi nevarnimi snovmi, ladijskimi odpadki in trdimi odpadki. Leta 1997 je bil sprejet še 6. aneks, ki ureja onesnaževanje zraka z ladjmi.

V okviru Mednarodne pomorske organizacije IMO so prvič razpravljali o tem problemu na konferenci leta 1973 in sprejeli resolucijo, ki je priznavala, da "balastne vode, ki morda vsebujejo bakterije nalezljivih boleznii, lahko, ko so izpuščene, povzročijo širjenje nalezljivih boleznii v druge države". Resolucija je s tem naložila IMO-u in Svetovni zdravstveni organizaciji World Health Organization (WHO), naj "se lotita študij tega problema na osnovi evidenc in predlogov, ki jih lahko dobijo od vlad" (IMO, 1998a). Tako je leta 1991 IMO-v Komite za zaščito morskega okolja (Marine Environment Protection Committee MEPC) sprejel *Navodila za preprečevanje vnosa nezaželenih organizmov in patogenov z izpusti ladijskih balastnih vod in sedimenta (Guidelines for preventing the introduction of unwanted organisms and pathogens from ships' ballast water and sediment discharge, Resolution MEPC 50(31))* (IMO, 1991).

Sodelovanje številnih znanstvenikov in strokovnjakov z raznih znanstvenih področij je obrodilo sadove, ko je novembra leta 1993 organizacija IMO sprejela *Navodila za preprečevanje vnosa nezaželenih organizmov in patogenov z izpusti balastnih vod in sedimenta*

*(Guidelines for preventing the Introduction of unwanted organisms and pathogens from ships' ballast waters and sediment discharges - IMO Assembly Resolution A.774(18))* (IMO, 1993). Navodila iz leta 1993 so bila kasneje dopolnjena in sprejeta kot *Navodila za nadzor in upravljanje ladijskih balastnih vod za zmanjšanje prenosa škodljivih morskih organizmov in patogenov (Guidelines for the control and management of ships' ballast water to minimize the transfer of harmful aquatic organisms and pathogens - IMO Assembly Resolution A.868(20))* (IMO, 1997). Treba je pripomniti, da je uporaba IMO-vih navodil danes še vedno le priporočljiva in ne pravno zavezujoča.

Nekatere države so z namenom, da bi zaščitile svoje vode, že v zgodnjih 90-tih uvedle posebna merila za nadzor balastnih vod. Omenil bi predvsem naslednja primera: v ZDA se je medvladna organizacija ANS Task Force "spopadla" s tem problemom na podlagi posebnega akta, imenovanega "*Nonindigenous Aquatic Nuisance Prevention and Control Act*", v Avstraliji pa je organizacija Australian Quarantine and Inspection Service (AQIS) v sklopu nacionalne strategije sprejela "*Australian Ballast Water Management Guidelines*". Po podatkih IMO so poleg Avstralije in ZDA uvedli obvezno ali priporočljivo kontrolo in merila še v nekaterih drugih pomorskih državah. Te so Kanada, Izrael, Čile, Panama (Panamski kanal), Argentina in Nova Zelandija (IMO, 1998a).

Področje varnosti plovbe in preprečevanja onesnaževanja morja v Sloveniji urejajo: Zakon o pomorski in notranji plovbi (UL SFRJ, 22/77); Zakon o varstvu okolja (UL RS, 1/96); in Mednarodna konvencija o preprečevanju onesnaževanja morja - MARPOL 73/78. Navedena zakonodaja problematiko vnosa škodljivih tujerodnih organizmov in patogenov z balastnimi vodami ne ureja. Tudi naš "novi" predlog zakona - Pomorski zakonik republike Slovenije (Poročevalec Državnega zbora republike Slovenije, št. 21/99, 07/04/99) - ni prinesel kakšnega napredka na tem področju.

### Upravljanje z balastnimi vodami in nadzor

Navodila so namenjena vladnim in drugim oblastem, poveljnikom ladij, ladjarjem, operaterjem, luškimi oblastem in drugim udeležencem v pomorskem prometu (IMO, 1997; IMO, 1999a, b, c, d).

Luške oblasti morajo zagotoviti širitev informacij o zahtevanih postopkih upravljanja balastnih vod in sedimenta. Zagotoviti morajo ustrezne "deponije" za sprejem in "tretiranje" balastnih vod in sedimenta. Uresničevale naj bi osnovni nadzor nad biološkim stanjem voda v svojem pristanišču in širila informacije o rezultatih raziskav. Uvesti morajo ustrezen nadzor (monitoring) z jemanjem vzorcev balastnih vod in sedimenta na ladjah. Pri opravljanju kontrolnih postopkov morajo biti pozorni, da ne bi prišlo do nepotrebnih zastojev ladij ob

pridobivanju prostega prometa s kopnim.

Ladjarji morajo biti seznanjeni z zahtevami luških-upravnih oblasti. Po pravilih morajo na ladji določiti odgovornega oficirja, ki bi zagotovil spremljanje in beleženje vseh postopkov v zvezi z balastnimi vodami, kot so: kdaj in na katerem geografskem položaju je bila napolnjena ali izpuščena voda v/z balastnih tankov ter temperatura, slanost in količina balastne vode.

Na ladjah morajo narediti vse kar je v njihovi moči, da ne polnijo balastnih tankov z vodo, katerega stanja ne poznajo. Prav tako to velja, ko je voda polna sedimenta, ki se je dvignil z dna zaradi delovanja ladijskega vijaka, ali kadar jih luške-upravne oblasti obvestijo, da obstaja posebna nevarnost. Čiščenje sedimenta iz balastnih tankov pa mora biti opravljeno na odprtem morju, v suhem doku ali pod nadzorom v pristanišču.

Predvidene so uporabe sledečih tehnologij oz. metod:

- izmenjava balastnih vod na odprtem morju;
- uporaba sodobnih tehnologij filtracije, dezinfekcije ali UV-debakterizacije;
- ladja ne sme izpustiti oz. lahko izpusti le minimalne količine balastne vode ali
- uporaba ustreznih "deponij" za balastno vodo in sediment.

Raziskave so pokazale, da organizmi, ki živijo v vodah luk, rečnih izlivov oz. v obalnih vodah, izpuščeni na odprtem oceanu, kot tudi obratno, organizmi z odprtega oceana, izpuščeni v obalnih vodah, v glavnem ne preživijo. Tako je izmenjava balastnih vod na odprtem oceanu lahko zelo učinkovit način zmanjšanja nevarnosti prenosa škodljivih organizmov in patogenov.

Uporabni metodi izmenjave balastnih vod na morju: "Zaporedna metoda" (sequential method), pri kateri balastne tanke na odprtem morju najprej zaporedoma, drugega za drugim, izpraznijo, nato pa napolnijo s svežo morsk vodo. Pri tej metodi je treba posvetiti veliko pozornosti začasnemu zmanjšanju stabilnosti ladje, celoten postopek pa mora biti izpeljan v ugodnih vremenskih razmerah in pod strogim nadzorom odgovorne osebe. Postopek nadzora vključuje:

- vzdrževanje ustrezne stabilnosti ladje ob upoštevanju efekta prostih površin,
- upoštevanje strižnih sil in upogibnih momentov,
- preprečevanje nastanka nadtlaka ali podtlaka v balastnih tankih in
- preverjanje, da v času polnjenja ali praznjenja natančno določenega balastnega tanka ne pride do polnjenja ali praznjenja katerega koli drugega balastnega tanka.

Pri izpeljavi vseh postopkov je treba zagotoviti ustrezno stopnjo varnosti tudi ob upoštevanju neugodnih okoliščin, kot so: nenadno poslabšanje vremena ali odpoved črpalke za balastno vodo, kar bi lahko ogrozilo varnost plovbe.

"Pretočna metoda" (Flow-through method), pri kateri na odprtem morju tanke balastne vode kontinuirano polnijo s svežo morsk vodo, pri tem pa višek balastne vode odteka skozi odzračevalne odprtine. Tudi pri tej metodi morajo biti vsi postopki ustrezno nadzorovani in varno izpeljani, tako kot pri zaporedni metodi. Raziskave so pokazale, da je za učinkovito izmenjavo vode pri tej metodi potrebna vsaj trikratna količina vode glede na kapaciteto balastnih tankov.

Vlada mora s svojimi organizacijami za usposabljanje zagotoviti ustrezno usposobljenost poveljnikov ladij in posadk za upravljanje balastnih vod po navodilih IMO kot tudi seznanjenost s postopki vodenja ustrezne dokumentacije (IMO, 1997; IMO, 1999a, b, c, d).

### Pripravljenost Slovenije na tem področju

Skupščina Republike Slovenije je 7. marca 1991 sprejela Resolucijo o pomorski usmeritvi Republike Slovenije (UL RS, 10/91), kjer v drugi točki pravi "Republika Slovenija bo skrbela za umno rabo obalnega območja in ohranjanje kulturne dediščine. Zato bo: a.) z ustanovitvijo službe za stalno nadziranje stanja morja in drugimi ukrepi zagotavljala pogoje za izboljšanje kakovosti obalnega morja." V tretjem členu pa še navaja: "Republika Slovenija bo skrbela za pomorsko pravno ureditev skladno z mednarodnimi pravili.

Zato bo: a.) razvila službo ali službe, ki bodo skrbele za nadzor morja in obale na varnostnem, plovbnem, ekološkem, sanitarno zdravstvenem in fiskalnem področju."

V publikaciji Prometna politika za vsakogar (MPZ, 1998), je zelo nazorno predstavljena problematika prometa po posameznih prometnih vejah. Kot cilja prometne politike na področju varovanja okolja sta med drugimi navedena "ohranitev identitete in biološke pestrosti prostora" in "ozaveščanje ljudi glede varovanja okolja". Pod ukrepi prometne politike pa lahko med drugimi preberemo: "Onesnaženje morja se bo zmanjšalo z ureditvijo pristanišč ter s prilagajanjem naših predpisov predpisom EU, na splošno pa se bo z več prispevki na temo varstva okolja v vseh javnih občilih vplivalo na ozaveščanje ljudi."

SFRJ je postala članica organizacije IMO leta 1960, Slovenija kot samostojna država pa leta 1993. Kakšno je današnje stanje pripravljenosti Slovenije glede preprečevanja vnosa škodljivih tujerodnih organizmov in patogenov z balastnimi vodami in sedimentom? Organizacija IMO je 28.04.1998 poslala svojim državam članicam vprašalnik, ki se nanaša na pripravljenost držav na področju problematike vnosa tujerodnih organizmov z balastnimi vodami in nadzora (IMO, 1999e). Glede na odgovore, ki so bili dani s strani Slovenije, sem ugotovil, da je pri nas za to določena Uprava republike Slovenije za pomorstvo in promet s sedežem na Lkmarjevi 2 v Kopru, kot alternativa za pridobivanje

informacij pa Nacionalni inštitut za biologijo, Morska biološka postaja iz Pirana (MBP).

Za ugotovitev stanja sem v zadnjem tednu v oktobru 1999 obiskal omenjeni organizaciji. Na Upravi republike Slovenije za pomorstvo in promet sem ugotovil, da na tem področju ne vodijo nobenih aktivnosti. Na MBP Piran sem zvedel, da v okviru obstoječih projektov opravljajo raziskave, povezane s stanjem morja in biotsko raznovrstnostjo, njihove smernice pa predvidevajo nadaljevanje dela na teh projektih in vključitev v nove projekte, ki bi se neposredno nanašali na raziskavo problematike, nadzor in odpravo posledic vnosa tujerodnih organizmov z balastnimi vodami.

### Smernice za zmanjšanje vplivov

Na srečanju IMO-vega komiteja MEPC 10. julija leta 1998 je ena izmed delovnih skupin (Ballast water working group) poročala o napredkih s področja razvoja novih pravil o upravljanju balastnih vod. Za uvedbo pravnomočnosti le-teh, je predlagala tri možne načine, in to:

- razvoj novega "Protokola" kot aneksa k resoluciji Marpol 73/78,
- popravek Marpol-a 73/78 z dodanim novim aneksom h konvenciji ali
- s prejetjem nove konvencije (MEPC, 42/8/1).

Sprejem pravil je predviden na diplomatski konferenci v letu 2000/2001 (IMO, 1998c).

Skladno z varnostnimi navodili iz 2. Aneksa IMO-ve Resolucije A.868(20) je oddelek pri Obalni straži ZDA pridobil študijo o varnosti izmenjave balastnih vod na kontejnerskih ladjah Panamax na odprtem morju (U.S. Coast Guard - Naval Architecture Division, 1999). Študija (*An Investigaton into the Impacts of Performing a Ballast Water Exchange at Sea on Typical Panamax Containership*), izvedena na ladjah treh različnih velikosti je pokazala, da se lahko na teh ladjah varno opravi izmenjava balastnih vod (BWE - Ballast Water exchange) na odprtem morju (Designers & Planners Inc. and Herbert Engineering Corp., 1998).

V sodelovanju z Intertankom je Mednarodna pomorska zbornica ICS (International Chamber of Shipping) razvila predlogo Modela za upravljanje z balastnih vod (*Model Ballast Water Management Plan, ICS/Intertanko, 1998*), ki je skladen z navodili IMO (A.868(20)). Model je namenjen ladjarjem v pomoč pri izdelavi lastnega modela za posamezne vrste ladij.

Avstralija je decembra 1998 sprejela politične smernice, imenovane "*Australia's Oceans Policy*", ki urejajo področje izkoriščanja morskih virov, v tem sklopu pa tudi enoten režim upravljanja balastnih vod (AQUIS, 1999).

ZDA so tudi uvedle režim upravljanja balastnih vod, in to za vse ladje, ki plujejo po reki Hudson severno od mostu George Washington, ladje na poti v Velika jezera,

kot tudi za ladje, ki so namenjene v vsa druga pristanišča ZDA. Na posebno pomembnost tega problema je opozoril tudi ukrep samega predsednika Clintona, ki je 3. februarja 1999 izdal "izvršilni ukaz" (Executive order) za preprečevanje vnosa škodljivih tujerodnih organizmov, nadzorovanje stanja na tem področju in odpravljanje škodljivih posledic. V ta namen je ukazal ustanovitev novega vladnega telesa, imenovanega "*Invasive Species Council*" (THE WHITE HOUSE, 1999).

### ZAKLJUČEK

V slovenskem morju do danes nismo zabeležili primera vnosa škodljivih tujerodnih organizmov, ki bi imel hujše posledice za rastline, živali, ljudi ali gospodarstvo. To je morda tudi vzrok, da pri nas do danes ni bilo veliko storjenega za varovanje morskega okolja in ljudi pred vnosi škodljivih organizmov.

Zavedati se je treba, da je slovensko morje kot del severnega Jadrana nenehno izpostavljeno tej nevarnosti, ki jo povzročajo ladje, ki vplujejo v severnojadranska pristanišča. Zato bo treba zagotoviti stalno opazovanje sprememb v morski flori in favni kot posledice vnosa tujerodnih organizmov, ter hkrati vzpostaviti mehanizme nadzora nad balastnimi vodami ladij, ki priplujejo v naše vode.

Po vseh dosedanjih prizadevanjih številnih mednarodnih organizacij, različnih znanstvenikov in strokovnjakov je pomembno "uzakonjenje" IMO-vih pravil za upravljanje balastnih vod, ki bi takoj stopila v veljavo. Z vidika varovanja okolja in zdravja ljudi je pomembno vzpostaviti mehanizme nadzora, ki bodo delovali po načelih kakovosti in rednosti. Nikakor pa ne smemo pozabiti na ladjarje in Luko Koper, za katere bo izjemno pomembno, da bodo postopki stekli hitro in nemoteče. Zastoji ladje zaradi raznih upravnih postopkov namreč pomenijo večanje stroškov za ladjarja, posledično pa lahko celo odločitev ladjarja, da v prihodnje izbere drugo pristanišče.

Iz vsega navedenega je razvidno, da gre za zelo kompleksen problem, ki ga ne bo možno rešiti "čez noč". Zato je smiselno upati, da se bodo vsi naši organi, institucije oz. druge ustanove, od katerih je odvisna urejenost na tem področju, čim prej odločili za načelo "bolje preprečiti kot zdraviti".

### ZAHVALA

Za vztrajno spodbudo, konstruktivne nasvete in pomoč pri iskanju strokovne literature se iskreno zahvaljujem doc. dr. Lovrencu Lipeju. Za strokovni pregled rokopisa in dragocene nasvete se zahvaljujem prof. dr. Liviju Jakominu. Posebno zahvalo sem še dolžan raziskovalcem z Morske biološke postaje iz Pirana kot tudi zaposlenim na Upravi Republike Slovenije za pomorstvo iz Kopra.

## INTRODUCTION OF NONINDIGENOUS ORGANISMS IN THE NORTHERN ADRIATIC AND BALLAST WATER MANAGEMENT

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## SUMMARY

*The article calls our attention to the existing dangers of nonindigenous organisms being introduced in our sea with ballast water and to the need to have this matter strictly under control. Some plankton investigations have proved that various types of bacteria as well as plant and animal species can survive in ballast water and sediment even after a journey lasting for a few months. The ballast water, filled on one side of the world and emptied on the other, can contain some harmful nonindigenous organisms.*

*Although only a minor research of this kind has been carried out in Slovenia and in the Adriatic Sea in general, no case of a harmful introduction of nonindigenous organisms in our sea that would badly affect the plants, animals, people or economy has been recorded to date. The Slovene sea, as part of the Northern Adriatic, has been constantly exposed to such dangers caused primarily by the ships docking in Northern Adriatic ports.*

*Introduction of nonindigenous organisms with ballast water and its control is a very complex problem. This means that we will have to provide for a constant monitoring of the changes in marine flora and fauna as a result of nonindigenous organisms being introduced in our sea as well as to restore mechanisms of control over ballast waters of the ships sailing in our sea. The competent bodies and institutions will certainly have to tackle this problem as soon as possible. The author of the article thus proposes a consistent consideration of the regulations issued by the International Maritime Organization (IMO).*

**Key words:** ballast water, nonindigenous species, management, Slovenian sea, northern Adriatic

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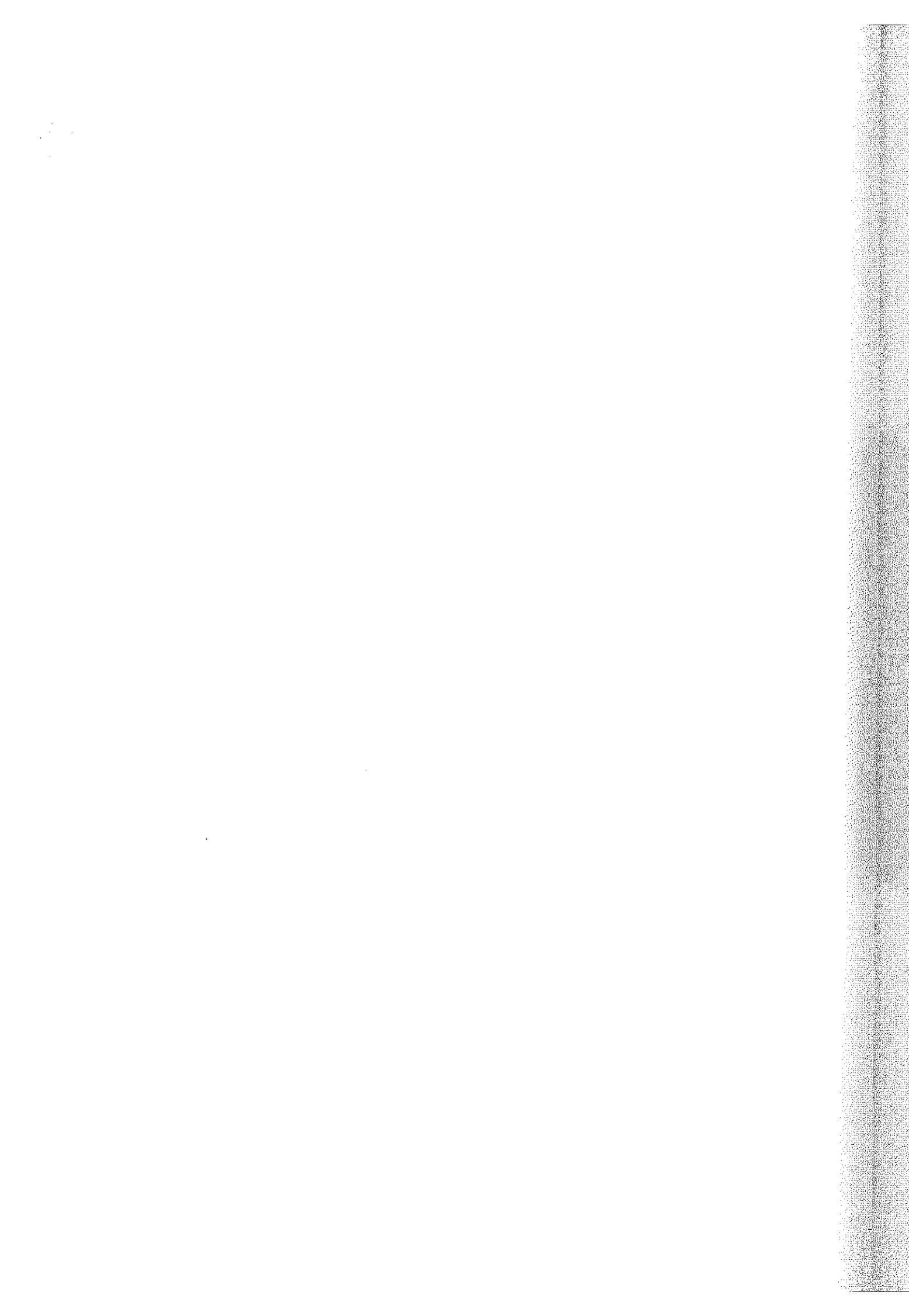
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IHTIOLOGIJA

ITTIOLOGIA

ICHTHYOLOGY



## EARLY LIFE HISTORY STAGES OF FAMILY CENTROLOPHIDAE IN THE EASTERN ADRIATIC

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### ABSTRACT

*Use of early life history stages of fish in systematic and ecological studies has increased in recent years. It is now recognized that eggs, larvae and juveniles present a wide array of characters that are largely independent of adult characters and suitable for a systematic analysis. Fisheries recruitment studies focus on the survival of eggs and larvae as the most important factor influencing variations in population abundance. A requisite to these studies is detailed information on the appearance of fish eggs and larvae in order to identify them in plankton samples. This paper reviews all available information on the early developmental stages of the family Centrolophidae found in the eastern Adriatic.*

**Key words:** early developmental stages, Centrolophidae, eastern Adriatic

### INTRODUCTION

The importance of early-life-history studies to fisheries investigations and phylogenetic research has increased dramatically during the last decade. Early-life-history stages are now routinely used in fisheries studies to investigate the interannual variation in recruitment (Wooster, 1983), and in studies of the phylogeny of fishes (Moser *et al.*, 1984). The study of fish eggs, larvae and juveniles is a key component in research into the biology, systematics and even population dynamics of fishes, in that it provides information on spawning areas and periods of many species. By combining the location of eggs, larvae, juveniles and adults of a species with information on the surrounding environment, possible environmental effects on spawning (egg and larval transport, *etc.*) can be inferred. Studies of this type contribute to our understanding of the early stages of development of fishes, which for certain species are still completely unknown. Consideration of the factors that affect egg and larval survival is fundamental, since it is the early stages of development that will eventually determine the existence of good or bad year classes. This is one of the main thrusts of ichthyoplankton studies in those areas in which the requisite basic information is available (egg and larval surveys in spawning areas

during the spawning season, *etc.*) for the species of interest.

The object of this paper is to compile and present all available information on both the early development stages of the eggs and larvae of the family Centrolophidae found in the eastern Adriatic and possible spawning areas and seasons of some species of the family.

### MATERIAL AND METHODS

The present paper sets out descriptions of the eggs, yolk-sac larvae, larvae and juveniles of the family Centrolophidae likely to be collected in plankton samples in the eastern Adriatic, together with information on the possible spawning areas and seasons for some species. The egg and larval descriptions have mostly been taken from the existing literature. In some cases the descriptions were done by the author himself based on material collected during surveys; in other instances the descriptions were published by other researchers, either for eggs, larvae and juveniles actually collected in the eastern Adriatic itself or for egg and larval material collected in other areas but for species that also inhabit the waters of the eastern Adriatic. Notochord (NL) length was measured for preflexion and standard length (SL) for flexion larvae, and total length for larvae and juveniles (TL).

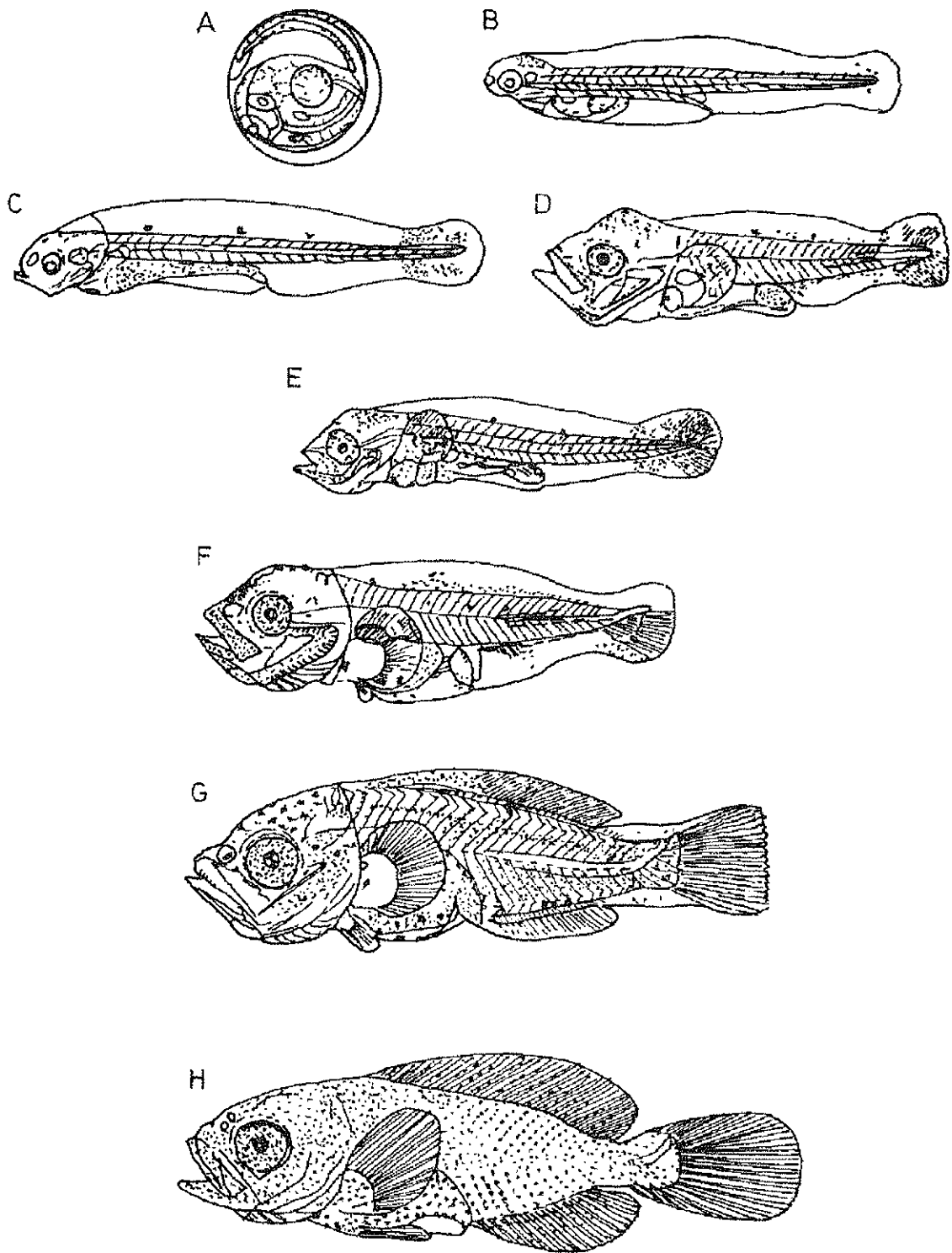


Fig. 1: *Centrolophus niger* (Gmelin, 1789). (A) egg; (B) yolk-sac larva, 4.4 mm TL; (C) larva, 5.0 mm TL; (D) larva, 5.4 mm TL; (E) larva, 5.6 mm TL; (F) larva, 6.7 mm TL; (G) larva 8.3 mm TL; (H) early juvenile, 17.2 mm TL (after Sanzo, 1932).

Sl. 1: *Centrolophus niger* (Gmelin, 1789). (A) ikra; (B) larva z rumenjarkovo vrečko, 4,4 mm TL; (C) larva, 5,0 mm TL; (D) larva, 5,4 mm TL; (E) larva, 5,6 mm TL; (F) larva, 6,7 mm TL; (G) larva 8,3 mm TL; (H) mladostni osebek v zgodnji fazi, 17,2 mm TL (po Sanzu, 1932).

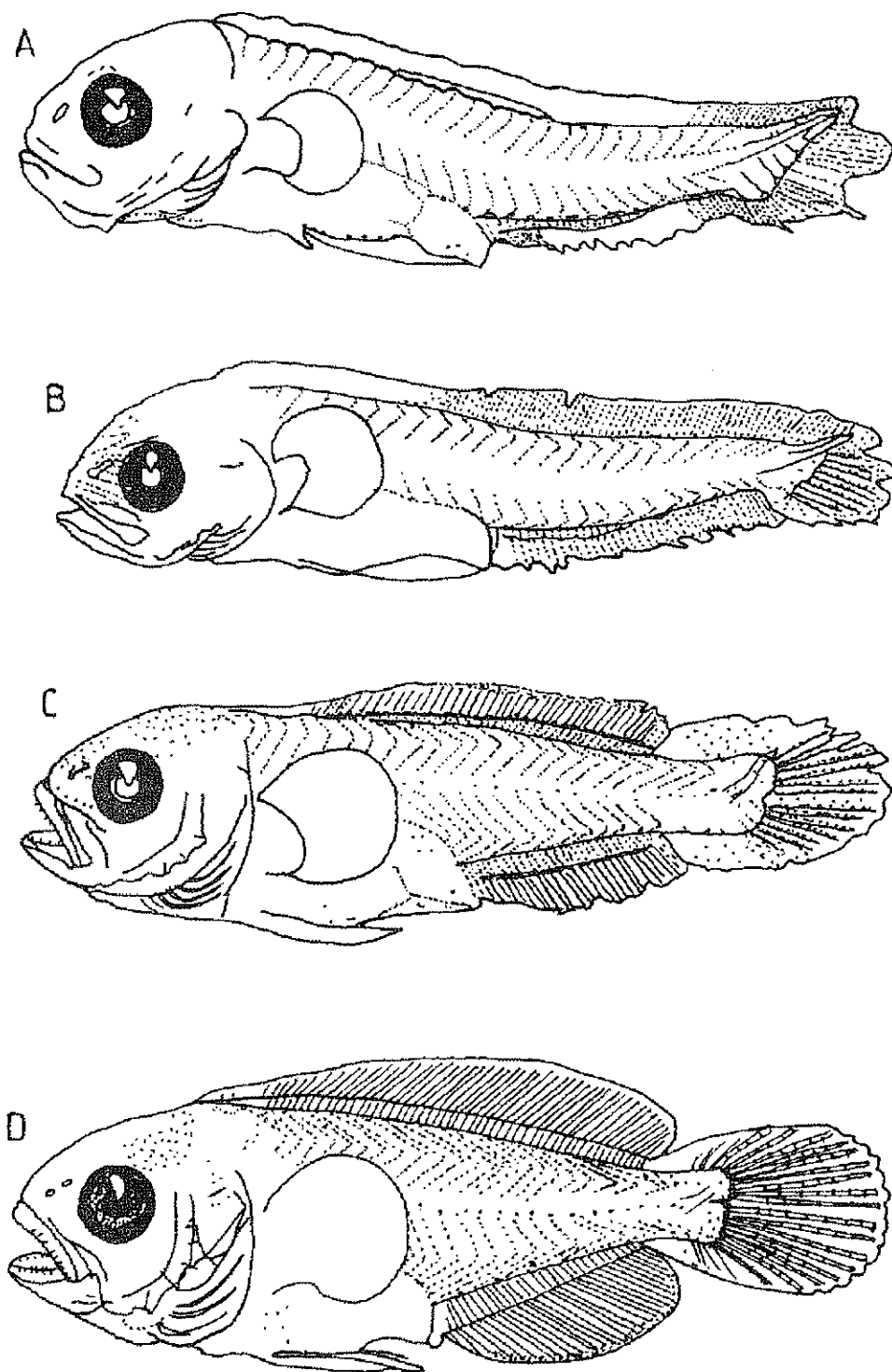


Fig. 2: *Schedophilus medusophagus* Cocco, 1839. (A) larva, 8.6 mm SL (after John & Karrer, 1987); (B) larva, 9.7 mm SL (original drawn by author); (C) larva, 11.8 mm SL (original drawn by author); (D) larva, 16.8 mm SL (after John & Karrer, 1987).

Sl. 2: *Schedophilus medusophagus* Cocco, 1839. (A) larva, 8,6 mm SL (po Johnu & Karrerju, 1987); (B) larva, 9,7 mm SL (izvirna risba je avtorjeva); (C) larva, 11,8 mm SL (izvirna risba je avtorjeva); (D) larva, 16,8 mm SL (po Johnu & Karrerju, 1987).

## RESULTS AND DISCUSSION

*Centrolophus niger* (Gmelin, 1789)

## Eggs

The eggs are spherical and measure 1.20-1.24 mm in diameter, with an oil globule 0.32 mm in diameter. The yolk is segmented, the perivitelline space narrow, and the chorion smooth. Melanophores are visible over the surface of the oil globule after the embryo has formed, and a series of pigment patches are present on the embryo itself (Fig. 1A) (Sanzo, 1932). No eggs attributable to this species have been collected during any of the survey carried out in the eastern Adriatic.

## Larvae

Regner (1982) found *C. niger* larvae at the station Stončica (43°00'N, 16°20'E) in the middle Adriatic in October and November with frequency 0.08%.

## Morphology

The body is rather slender during the early stages, with body depth increasing with development. Body depth at the base of the pectoral fin is 13% of NL at 4.36 mm, 30% of SL at 8.32 mm TL, and 21% of SL at 17.2 mm TL (Figs. 1B, C, H). The gut is quite narrow and straight in the early stages, extending to 57% of NL in newly hatched larvae and to 59% of SL at 8.32 mm TL; gut diameter also increases with growth. Head length also increases as development progresses, representing 20% of NL in first-feeding larvae and 33% of SL in postflexion larvae and early juveniles. Unlike other stromateoid species, the larvae of this species bear no spines on the preopercle.

## Pigmentation

The basic pigmentation pattern in all stages of development consists of some stellate melanophores on the top of the head, melanophores along the dorsal and ventral margins of the body, a row of melanophores below the gut, and a cluster of pigment spots on the caudal tip. This latter pigmentation on the caudal tip is located on the finfold in preflexion larvae, but becomes embedded inside the body in postflexion larvae. In newly hatched larvae measuring 4.4 mm TL (Fig. 1B), there are 4 large pigment patches on the dorsal margin of the body and another 4 on the ventral margin, somewhat staggered with respect to the former. With growth these pigment spots on the contours of the body become smaller, particularly the ventral ones, which turn into a rather continuous series of small spots. In a 5.4 mm TL specimen (Fig. 1D) a longitudinal row of pigment spots

begins to develop medially on the lateral walls of the tail. Pigmentation in early juveniles 17.2 mm TL (Fig. 1H) consists of small punctiform melanophores that spread over the entire body and on the proximal portion of the dorsal and anal fin rays.

## Notochordal flexion

Notochordal flexion had already commenced in a 6.72 mm TL larvae (Fig. 1F) described by Padoa (1956).

## Fin development

The rays of the caudal fin are the first to develop completely, followed by those of the dorsal, anal, pelvic, and pectoral fins. All the rays in the caudal, dorsal, anal, and pelvic fins were fully developed in a 8.32 mm TL specimen (Fig. 1G), but formation of the rays in the pectoral fins was still not complete even in a 17.2 mm TL specimens. Pelvic fin buds appeared in a 6.72 mm TL specimen (Padoa, 1956). There are 25 myomeres, 11 preanal and 14 caudal.

## Juvenile

The specimen of the juvenile stage of the *C. niger* was found by west of Island of Vis, in the area of the Stončica observation station (43°00'N, 16°20'E). This was the first juvenile stage of this species found in the middle Adriatic (Karlovac, 1974). Measuring 27.99 mm in total length, it was caught on November 8th, 1971 by a vertical haul of the Helgoland type of plankton net, hauled from a depth of 75 m to the surface. Owing to the greater depth of its body, the juvenile specimen is rather squat, with the following properties: the standard length is 2.68 times as large as the depth of body (at the beginning of the dorsal fin base), and 2.56 time as large as the head length. Numerical values of rays in the various fins are the following: the caudal fin rays are somewhat shorter in the middle, comprising altogether 15 bifurcating and 2 simple ones; additional few rays are on the sides. The dorsal fin omprises 7 shorter and 33 longer rays, totalling 40 rays (Karlovac, 1974). The anal fin extends from the vicinity of anus to the end of the caudal peduncle, where ends at the same level as the dorsal fin. It comprises 3 shorter rays followed by 20 longer ones, totalling 23 rays. The pectoral fins are rounded, covering a larger part of the body's depth. Each of the fins has 18 rays. The ventral fins extend as far as the anus. The pigmentation of the preserved specimen is the following: four transverse wide black belts are conspicuous. The first belt is on the fore part of the body, just behind the gill cover; the second begins before the anus, extending headwards; the third is located between the caudal peduncle and anus, while the fourth, of a lesser intensity, comprises the caudal peduncle (Karlovac, 1974).



*Schedophilus medusophagus* (Cocco, 1839)**Pigmentation****Eggs**

No information available.

**Larvae**

Two larvae of this species were caught by a Hensen net at station Stončica on 21 June 1994, and this is the first larval record from the Adriatic Sea (Dulčić, 1998). After fixation in 4% seawater formalin, the standard lengths of larvae were 9.7 mm and 11.8 mm (Figs. 2B and 2C).

**Morphology**

The general morphology largely conforms to that of other stromateoid species. Body depth augments over the course of development. Maximum body depth is approximately 25% of length in larvae measuring 8.6 mm NL, 30% at larval lengths between 9.5 and 13 mm SL, and 30-35% of SL in larger postlarvae. In early juveniles maximum body depth represents a still larger proportion of SL, 47% in specimens 16.8 mm SL (Fig. 2D). Spines are visible on the margin of the preopercle in individuals larger than 9.5 mm SL, and become somewhat elongate and increase in number with body length (John & Karrer, 1987).

The most outstanding feature of the pigmentation pattern is two series of internal stellate pigment dots along the dorsal and ventral contours of the body, ending at the caudal tip. The dorsal series starts at the body's first myomere, the ventral series starts on the walls of the peritoneum. A row of small melanophores is present below the gut in all stages of larval development. The dorsal portion of the head is covered by minute dots, which are less numerous to larval lengths smaller than 9.5 mm SL. At around 11 mm SL very light pigmentation is observable on the jaws and the angle of the lower jaw. Pigmentation also appears medially on the lateral walls of the body from approximately the first third of the body to the notochordal tip at around this same length. Pigmentation is usually present laterally at the end of the caudal peduncle, on the remnants of the finfold above and below the caudal peduncle, and on the anterior portion of the caudal fin. The pelvic fins are lightly pigmented at 10.9 mm SL.

**Notochordal flexion**

Notochordal flexion takes place at between 8 and 9.5 mm SL (John & Karrer, 1987).

**Fin development**

The caudal fin is the first fin in which formation of the full complement of rays is complete. Pelvic fin buds were already visible in the smallest specimens described (around 8.5 mm in SL) (Fig. 2A).

## ZGODNJI RAZVOJNI STADIJ RIB IZ DRUŽINE CENTROLOPHIDAE V VZHODNEM JADRANU

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**POVZETEK**

V zadnjih letih postaja vse pomembnejše preučevanje zgodnjih razvojnih stadijev v sistematičnem in ekološkem raziskovanju rib. Tako je danes že splošno uveljavljeno prepričanje, da iker in larve pomenijo širok spekter bitij, ki so bolj ali manj neodvisna od odraslih bitij in kot taka primerna za sistematično analizo. Študije o prirastku ribjih populacij se osredotočajo na preživetje iker in larv kot najpomembnejšega dejavnika, ki vpliva na spremembe v številnosti ribjih populacij. Prvi pogoj za te študije so podrobne informacije o videzu iker in larv, da bi jih lahko identificirali v planktonskih vzorcih. V tem članku so zajeti vsi razpoložljivi podatki o zgodnjih razvojnih stadijih rib iz družine Centrolophidae v vzhodnem Jadranu.

**Ključne besede:** zgodnji razvojni stadiji rib, Centrolophidae, vzhodni Jadran

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## NEW RECORD AND SOME MORPHOLOGICAL DATA OF THE BASKING SHARK, *CETORHINUS MAXIMUS* (GUNNERUS, 1765), IN THE EASTERN ADRIATIC

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### ABSTRACT

On March 23<sup>rd</sup> 1999, a Basking Shark, *Cetorhinus maximus* (Gunnerus, 1765), was caught in gillnet and found by fishermen near Osobljava harbour on the Pelješac peninsula. The paper gives some morphological and meristic data and general information about the species and its occurrence in the Adriatic.

**Key words:** Basking Shark, *Cetorhinus maximus*, Eastern Adriatic

### INTRODUCTION

The Basking Shark, *Cetorhinus maximus* (Gunnerus, 1765), is a coastal-pelagic shark found in boreal to warm temperate waters of the continental and insular shelves, occurring well offshore and often very close to land, enters enclosed bays (Compagno, 1984).

It has 5 extremely long gill slits that virtually encircle the whole head. The snout is pointed, with huge sub-terminal mouth. Nostrils are widely separated from mouth. Colour is grayish-brown to slaty gray, or nearly black above (Bigelow & Schroeder, 1948), belly similar or lighter, often with light patches or bands on belly and under snout (Quero, 1984). Size of males is to 9 m, females to 9.8 m with reported maximum of 15.2 m (Compagno, 1984; Quero, 1984; Fischer *et al.*, 1987). The Basking Shark is the second largest shark, after the Whale Shark, *Rhiniodon typus*, and it can reach a weight of 8000 kg (Bini, 1967). It is ovoviviparous (Compagno, 1984; Quero, 1984) and it reaches sexual maturity at the age of 3-4 years (Fischer *et al.*, 1987). Juveniles below 3 m long are extremely rare, but there are records of free-living individuals about 170 cm long (Bigelow & Schroeder, 1948; Compagno, 1984).

The diet of the Basking Shark consists wholly of

small planktonic organisms, which it sifts out of water by means of its gill rakers (Bigelow & Schroeder, 1948). It is capable of filtering over 2000 tons of water per hour assuming constant cruising speed of about 2 knots (Compagno, 1984). The Basking Shark is often seen at or near the surface, singly, in pairs, triads or in schools up to a hundred or more individuals, basking with dorsal fins out of water or even with bellies upward, or moving slowly forward or in short arcs with their mouths open like hoops while feeding. Surface basking in this shark is thought to be correlated with surface concentrations of food plankton and also with courtship and mating (Compagno, 1984). It is not considered as dangerous for humans, except if attacked.

### MATERIAL AND METHODS

The Basking Shark was found by fishermen near Osobljava harbour on the Pelješac peninsula in the southeastern Adriatic on 23<sup>rd</sup> March 1999 (Fig. 1). It was caught in common gillnet. The specimen was preserved and easily identified according to Jardas (1996). Morphometric characteristics were measured to the nearest cm (Fig. 2). Weight was measured by a heavy balance.

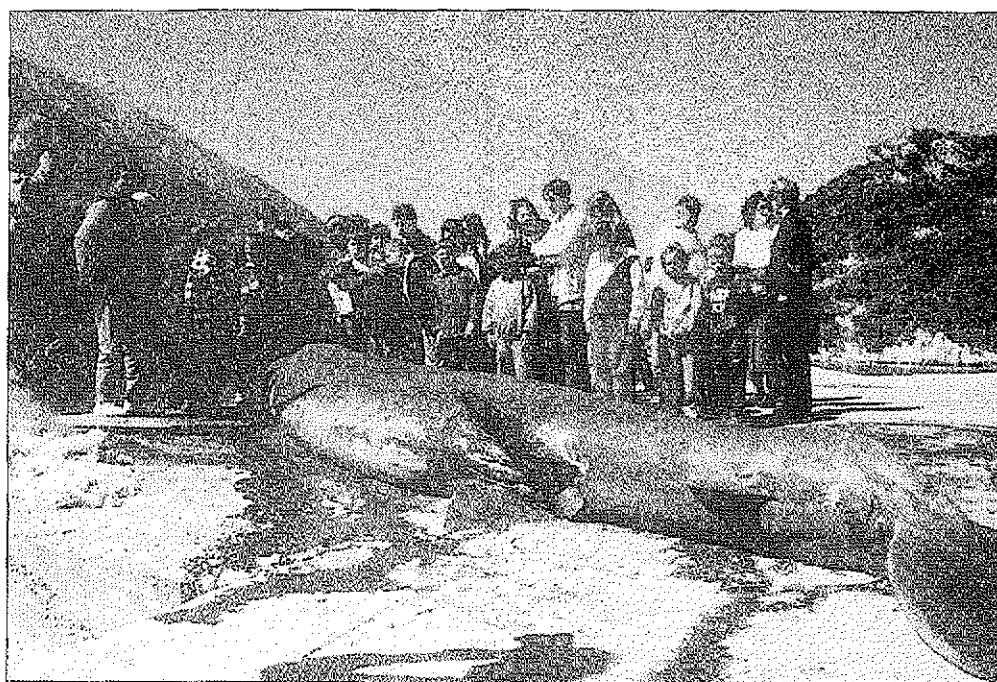


Fig. 1: The Basking Shark caught in gillnet near the Osobljava harbour on the Pelješac peninsula.  
 Sl. 1: Morski pes orjak, ujet v mrežo škrgarico v bližini pristanišča Osobljava na polotoku Pelješcu.

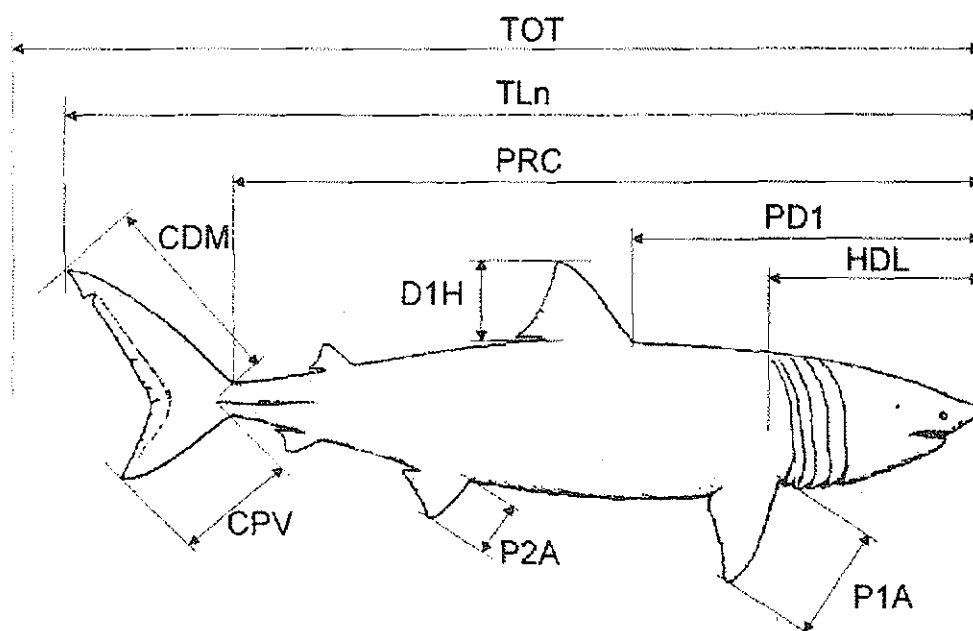


Fig. 2: The main morphometric characteristics of the Basking Shark: TOT - Total length; TLn - Total length with caudal fork in normal position; PRC - Precaudal length; PD1 - Pre-first dorsal length; HDL - Head length; CDM - Dorsal caudal margin; D1H - First dorsal length; CPV - Preventral caudal margin; P1A - Pectoral anterior margin; P2A - Pelvic anterior margin.

Sl. 2: Glavne morfometrične karakteristike morskega psa orjaka: TOT - celotna dolžina; TLn - celotna dolžina z repno vilico v normalnem položaju; PRC - dolžina brez repa; PD1 - dolžina do prve hrbtne plavuti; HDL - dolžina glave; CDM - dolžina roba zg. repne krpe; D1H - dolžina prve hrbtne plavuti; CPV - dolžina roba sp. repne krpe; P1A - dolžina prsne plavuti; P2A - dolžina trebušne plavuti.

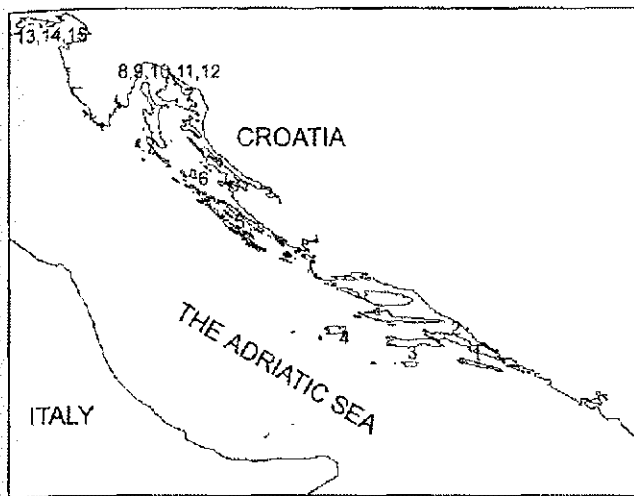


Fig. 3: Records of the Basking Shark with known position in the Eastern Adriatic: 1 - new record from the vicinity of Osobljava harbour; 2 - Ston; 3 - Korčula; 4 - Vis; 5 - Ugljan; 6 - Molat; 7 - Peškera; 8 - Kraljevica; 9 - Bakarac; 10 - Opatija; 11, 12 - Ičići; 13, 14, 15 - Gulf of Trieste.

Sl. 3: Zapisi o morskomu psu orjaku z znanimi najdišći v vzhodnem Jadranu: 1 - nov zapis iz bližine pristanišča Osobljava, 2 - Ston; 3 - Korčula; 4 - Vis; 5 - Ugljan; 6 - Molat; 7 - Peškera; 8 - Kraljevica; 9 - Bakarac; 10 - Patina; 11, 12 - Ičići; 13, 14, 15 - Tržaški zaliv.

RESULTS AND DISCUSSION

The Basking Shark is a relatively rare but constant species (Fig. 3) in The Adriatic (Tortonose, 1956; Bini, 1967; Milišić, 1994; Jardas, 1996). The very first record about this species was apparently made by Naccari (1822). During the 19<sup>th</sup> century, two more records were made, i.e. by Carrara (1846) and Brusina (1888). Hirtz (1909) reported about catching a Basking Shark near the island of Vis, while Valle reported on a specimen in 1922, but stated no place of this catch. Next records were made in 1931 near Bakarac and in 1934 near Kraljevica, while in 1937 a 3.5 m long specimen was caught in the waters of Korčula (Milišić, 1994). The specimen caught near Kraljevica was the largest, for it was 7.62 m long and weighed 2.400 kg (Jardas, 1996). Crnković (1957) and Milišić (1994) reported on a 4.70 m long specimen caught near Peškera in 1954. From 1968 there is a record of a specimen caught near Ston (2.5 m long), from 1981 of a 5.5 m long specimen caught near the island of Molat, and from 1985 of a 6.47 m long individual caught near Patina (Milišić, 1994). Bošnjak and Lipej (1992) reported about a Basking Shark from the Gulf of Trieste; in the same area a record was also made by Perco (1993). Two additional observations were made near Ičići in 1981 and 1991 by Kovačić (1993). The last report comes from Dulčić (1997), i.e. about a 7 m long

and 2.000 kg heavy specimen caught by two fishermen near the island of Ugljan.

The main morphometric characteristics of the caught specimen are given in table 1. Weight of the specimen was approximately 2.500 kg and it was a female.

Tab. 1: The main morphometric characteristics of the caught female specimen.

Tab. 1: Glavne morfometrične značilnosti ulovljene samice morskega psa orjaka.

|  |        |
|--|--------|
| TOT - Total length                                     | 722 cm |
| TLn - Total length with caudal fork in normal position | 687 cm |
| PRC - Precaudal length                                 | 586 cm |
| PD1 - Pre-first dorsal length                          | 261 cm |
| HDL - Head length                                      | 165 cm |
| CDM - Dorsal caudal margin                             | 135 cm |
| D1H - First dorsal length                              | 72 cm  |
| CPV - Preventral caudal margin                         | 95 cm  |
| P1A - Pectoral anterior margin                         | 27 cm  |
| P2A - Pelvic anterior margin                           | 29 cm  |

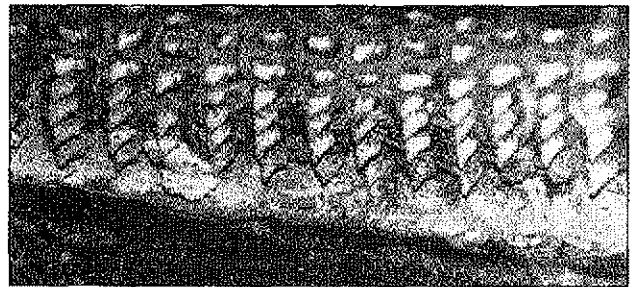


Fig. 4: Teeth of the Basking Shark in the lower jaw. Sl. 4: Zobje morskega psa orjaka v spodnji čeljusti.

Teeth in both jaws are similar and minute (Fig. 4). Height of the teeth in the smaller specimens is 3 mm, and about 6 mm in longer specimens (Bigelow & Schroeder, 1948). There are 4 to 7 functional series with 100 or more teeth in each row on each side of the jaw. Dieuzeide *et al.* (1953) are reporting 2.700 teeth for an 8.75 m long specimen. Teeth toward the center of the mouth are low and triangular, but those along the sides are conical, slightly recurved. They are somewhat compressed laterally, with a ridge on each side and with basal part striated. At the center of the upper jaw there is a wide space with only scattered teeth, which is not the case in the lower jaw (Soldo, 1996).

Two 2.5 m and 3.5 m long specimens are juveniles, if their lengths were reported correctly. Therefore, the following question was raised: Does the Basking Shark breed in the Eastern Adriatic? The Basking Shark is a highly migratory species (Compagno, 1984) and according to Bigelow & Schroeder (1948) it seems certain that young are produced throughout their entire range, for

small ones have been reported both from the north (Ireland, Norway) and from the south (Mediterranean). Existing records of the Basking Shark are only for individuals, so breeding can not be confirmed, but if we take into consideration that different sizes of the Basking Shark

have been reported throughout the Eastern Adriatic and that gestation period is 3.5 years (Compagno, 1984), the answer can be that the Basking Shark breeds somewhere out of the Adriatic but that it is possible that occasionally it brings forth its young in the waters of the Adriatic.

## NOV ZAPIS IN NEKAJ MORFOLOŠKIH PODATKOV O PSU ORJAKU *CETORHINUS MAXIMUS* (GÜNNERUS, 1765) IZ VZHODNEGA JADRANA

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### POVZETEK

Dne 23. marca 1999 so ribiči v bližini pristanišča Osobljava na polotoku Pelješac našli v mrežo škrgarico ujetega morskoga psa orjaka *Cetorhinus maximus* (Günnerus, 1765). V članku je navedenih nekaj morfoloških in merističnih podatkov o vrsti in o njenem pojavljanju v Jadranu.

**Ključne besede:** morski pes orjak, *Cetorhinus maximus*, vzhodni Jadran

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## AGE AND GROWTH STUDIES ON FISHES IN CROATIAN FISHERIES SCIENCE

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## ABSTRACT

Age and growth studies of fish species are one of the main analytical models to analyze the dynamics of exploited fish populations. In this study the author reviews the published data on age and growth parameters of some fish species in the Eastern Adriatic. Scales and otoliths were the main calcified tissues employed for age determination, while fin rays were scarcely used. Age and growth were determined for 17 fish species, which makes 14% of 120 commercially interesting species. According to presented results we can conclude that there is still much work to be done in age and growth determination of commercially interesting fish species.

**Key words:** age, growth, studies, Croatian fisheries

## INTRODUCTION

The demography of living organisms constitutes the research object of the population dynamics. Since changes in the number of individuals and the age structure of a population result from interactions between the biology of the species and the biotic and abiotic environments, the population dynamics can be fully considered a branch of ecology. As a quantitative discipline, the population dynamics uses mathematical models as a main tool. Most population dynamics models require previous work with biological models, or include them as submodels. In particular the following biological studies are of a great importance in ichthyology: stock identification, length-weight relationship, length-age relationship, sex ratio, proportion of mature individuals and trophic relationship.

Biological studies of fish presently being carried out in the Mediterranean reflect the wide interest in growth being shown by scientists. However, the diversity of the studied species, which ranges from pelagic to littoral, and demersal habitats is noteworthy, and reflects the multispecies nature of the Croatian fisheries. Species normally studied correspond to the exploited populations caught by a variety of fishing techniques: trawls, longlines, trammel nets, beach seine, etc.

In this paper I will attempt to present age and growth studies in the Croatian fisheries science.

## AGE AND GROWTH STUDIES

The study of growth means basically the determination of the body size as a function of age. Therefore all stock assessment methods work essentially with age composition data. In temperate waters, such as the Adriatic Sea, can usually be obtained through the counting of year rings on hard parts such as scales and otoliths. These rings are formed due to strong fluctuations in environmental conditions from summer to winter and vice versa. Von Bertalanffy growth model of body length as a function of age is one of the commonest models for observing growth of most fish species. The mathematical model is:  $L(t) = L_{\infty} (1 - \exp(-K(t-t_0)))$ , where the parameters can to some extent be interpreted biologically.  $L_{\infty}$  is interpreted as "the mean length of very old (strictly: infinitely old) fish", it is also called the "asymptotic length".  $K$  is a "curvature parameter", which determines how fast the fish approaches its  $L_{\infty}$ . The third parameter,  $t_0$ , sometimes called "the initial condition parameter", determines the point in time when the fish has zero length. Biologically, this has no meaning, because the growth begins at hatching when the larva already has a certain length, which may be called  $L(0)$  when we put  $t = 0$  at the day of birth.

The growth of sardine *Sardina pilchardus* (Walbaum, 1792) in the Eastern Adriatic was intensively studied (Mužinić, 1954; Sinovčić, 1983, 1986). The scales and otoliths were used for age determination. Calculated von

Bertalanffy's growth constants were:  $L_{\infty} = 20.5$  cm;  $K = 0.46$ ;  $t_0 = -0.5$ ; and sardine specimens sampled from commercial catches belonged from 1+ to 8+ age groups (Sinovčić, 1986).

Morović (1961) using otoliths and scales established age groups of several mugilids: *Mugil cephalus* (otoliths - 3°, scales - 6°), *Chelon labrosus* (otoliths - 5°, scales - 5°), *Liza aurata* (otoliths - 4°), and *Liza saliens* (otoliths - 4°).

Striped mullet, *Mullus barbatus* Linnaeus, 1758, was studied by Haidar (1970). Seven age groups were found (from 0° to 6°), using scales and otoliths, in the eastern Middle Adriatic.

Hake, *Merluccius merluccius* (Linnaeus, 1758), is, like sardine, one of commercially most important fish species in the Adriatic Sea, and it was intensively studied (Županović, 1961, 1968; Jardas, 1976; Županović & Jardas, 1986). Studying the age composition of hake from the Jabuka Pit, using otoliths, showed highest presence of age groups 1 and 2 (Županović & Jardas, 1986), while the maximum age found was 9 years (Županović, 1968).

Growth parameters of the red pandora *Pagellus erythrinus* (Linnaeus, 1758), obtained by graphic method, in the insular zone of the Middle Adriatic were:  $K = 0.201$  and  $L_{\infty} = 37.7$  cm. Scales were used for age determination and six age groups were obtained (Županović & Rijavec, 1980).

The growth of the Atlantic horse-mackerel *Trachurus trachurus* (Linnaeus, 1758) was studied by Alegria-Hernandez (1983, 1984). Calculated parameters of growth curve were:  $L_{\infty} = 37.55$  cm;  $K = 0.22$ ;  $t_0 = -1.28$ . Age was determined by otoliths and specimens belonged to 0 to 9 age group.

A study of biological characteristics of the grey mullet *Liza ramada* (Risso, 1826) was carried out over a period of one year in Šibenik area. The following values of von Bertalanffy's growth parameters were estimated:  $L_{\infty} = 52.5$  cm,  $K = 0.25$  and  $t_0 = -0.1$ . Grey mullet attains maximum length at 12 years of age. Parameters were obtained by Ford-Walford method from mean grey mullet lengths (Sinovčić *et al.*, 1986).

Bogue, *Boops boops* (Linnaeus, 1758) is also a very important exploited species in the Croatian fisheries. Growth of the bogue from the Middle Adriatic was studied by Alegria-Hernandez (1989). Mean length-at-age values were estimated from otoliths and analysis of polymodal length frequency distributions. Growth patterns were well described by von Bertalanffy growth equation. Growth parameters  $L_{\infty} = 338.89$  mm;  $K = 0.167$ , and  $t_0 = -1.296$  were calculated.

The growth of the Adriatic anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), was studied by Sinovčić (1992). The following values of von Bertalanffy's growth parameters were estimated:  $L_{\infty} = 19.4$  cm,  $K = 0.57$  and  $t_0 = -0.5$ . The anchovy attains maximum length at 4 years of age.

Tičina (1994) studied age of the tuna fish, *Thunnus thynnus* Linnaeus 1758, in the eastern part of the

Adriatic coast using the first spine of the first dorsal ray. He found that tuna between 0° and 4° age inhabit the Eastern Adriatic waters.

Age and growth were analysed for damselfish, *Chromis chromis* (Linnaeus, 1758), collected in the eastern Middle Adriatic Sea. Growth in length, not showing significant differences between sexes, was expressed for the whole sample using the Bertalanffy equation:  $L_t = 142.0 (1 - e^{-0.26(t + 0.30)})$ . Scales were collected from 1230 individuals. The damselfish is a relatively long-lived species. The oldest male and female were estimated to be 9 years old (Dulčić & Kraljević, 1995).

Age composition of the striped sea bream, *Lithognathus mormyrus* (Linnaeus, 1758), was established using the Bhattacharya method and additional observations on annual rings on scales. Six age classes were obtained from Kaštela Bay (age 3: 21.7 cm, age 4: 26.5 cm, age 5: 28.4 cm, age 6: 30.3 cm, age 7: 31.6 cm, age 8: 33.4 cm) and from Mirna Bay (age 2.5: 19.4 cm, age 3.5: 24.1 cm, age 4.5: 26.9 cm; age 5.5: 29.4 cm, age 6.5: 31.3 cm, age 7.5: 32.8 cm). Von Bertalanffy's growth equation was fitted to these mean length-at-age data resulting in parameter values of  $L_{\infty} = 36.2$  cm,  $K = 0.297$ ,  $t_0 = -0.08$  for Kaštela Bay, and  $L_{\infty} = 37.3$  cm,  $K = 0.262$ ,  $t_0 = -0.38$  for Mirna Bay (Kraljević *et al.*, 1995).

Aspects concerning age and growth were analysed in the golden grey mullet *Liza aurata* (Risso, 1810) collected in Mirna Bay (eastern Adriatic). Mean length and age data derived using scale readings were used to estimate the growth parameters of the Von Bertalanffy equation. The theoretical maximum length was estimated to be  $L_{\infty} = 398$  mm. The growth coefficient was  $K = 0.21$  and  $t_0 = -1.14$ . Seven age classes, ranging from 3+ to 8+ and 11+ years, were defined by the scale readings (Kraljević & Dulčić, 1996).

Growth of the black sea bream *Spondyliosoma cantharus* (Linnaeus, 1758) from the eastern Middle Adriatic was studied using data on the scales from 745 fish. The Von Bertalanffy growth equations was fitted on the basis of mean length-at-age data resulting in parameter values of  $L_{\infty} = 47.7$  cm,  $K = 0.178$  and  $t_0 = -0.27$ . The black sea bream is a long-lived species. The oldest male was estimated to be 14 and female 9 years old (Dulčić & Kraljević, 1996).

The age and growth of the gilt-head sea bream *Sparus aurata* Linnaeus, 1758 were determined from specimens collected in the Mirna Estuary (northern Adriatic). Mean length at age data, as derived using scale readings, were used to estimate the growth parameters of the von Bertalanffy equation:  $L_{\infty} = 59.8$  cm,  $K = 0.15$  and  $t_0 = -1.71$ . Twelve age classes ranging from 1 to 12 years were defined by scale readings (Kraljević & Dulčić, 1997). Maximum age of 22 years was found for the gilt head sea bream in the Eastern Adriatic with parameters  $L_{\infty} = 84.98$  cm,  $K = 0.073$  and  $t_0 = -2.823$  (Kraljević *et al.*, 1998).

Regarding methods, it is worthwhile emphasizing the increasing number of studies using PC-computers with adequate softwares (ELEFAN, FISHPARM, FISAT, etc.) to obtain data to improve understanding of recruitment and growth patterns. Scales and otoliths were the main calcified tissues employed for age determination, while fin rays were scarcely used. The daily growth rings in otoliths of fish larvae, which have been employed for both age and growth determination and for calculating birth-date distribution, are increasingly used in the Mediterranean (Morales-Nin, 1989, 1992; Palomera *et al.*, 1988) and Adriatic studies - for sardine, anchovy and sprat larvae (Dulčić, 1995, 1997, 1998). In general, it is clear that three main subjects arise: the need to validate results obtained, the problem of different stocks of the same species, and sampling limitations.

### VALIDATION METHODS

Age and growth studies are basic for the analysis and management of fishery resources and for biological studies. The methods most commonly used are those involved in counting concentric rings in scales and otoliths. The growth rates of these rings are directly related to time. The periodicity of the rings laid down in the calcified structures can be proved directly or indirectly. Direct methods involve rearing young fish and marking calcified structures. Rearing experiments are the most precise way to determine ring formation and periodicity, but cannot be applied to all species according to the otolith structure. The capture, marking of the fish and calcified tissue with an agent, such as tetracycline, and subsequent release have the advantage of allowing growth in natural conditions, but they are costly and limited to a few species. Indirect methods are based on the criteria of proportionality, seasonality, and back-calculation. The proportionality of fish growth and the calcified structure growth (otolith, scale, fin ray) are determined by means of regression methods. Seasonality of ring deposition can be analyzed by the monthly dis-

tribution of margin type (opaque or hyaline). If the rings are measured, the evolution of the value of the last ring completion (R) can be used for numerical determination:

$$R = R_n \times 100 / R_{n-1}$$

where  $R_n$  = is thickness of the last-deposited in the margin,  $R_{n-1}$  = is the thickness of the previous ring. However, when comparing these values, the decreasing thickness of consecutive rings should be kept in mind. The back-calculation of lengths by age is generally performed using the Fraser-Lee equation (Duncan, 1980):

$$SL_i = a + (SL - a) * R_i / LR$$

where  $SL_i$  is the standard length at previous age  $i$ ,  $a$  is the intercept of the regression line of standard length (SL) on otolith (or scale) radius (LR), and  $R_i$  is the  $i$ -th radius of the otolith. The back-calculated values should be close to the actual values obtained from recordings and should follow a Von Bertalanffy growth curve. Other methods must be developed in future based upon otolith composition, DNA/RNA ratios and lipofuscin analysis, since all the mentioned methods are already functioning in the world (Bennet *et al.*, 1982; Bulow, 1987; Hill & Radtke, 1988). The presence of various stocks in the same area could also cause differences in growth rates and age composition of a species. Stocks are discrete groups of fish, which show little mixing with adjacent groups. An essential feature is that population parameters should remain constant over the distribution area of the stock. There is still much work to be done in fish stock differentiation and delimitation, but recent advances in methodologies based on genetic analysis will bring an improvement to our knowledge and facilitate correct growth determination. One of the main problems is sampling limitations. Correct sampling is fundamental for age and growth studies, for it is necessary to sample the entire size range of the population. Sampling can be biased among the others by two main factors: equipment selectivity and unequal size (and age) distributions, for instance, bathymetric size distributions. The use of only juvenile fish for growth determination can give unrealistic growth parameters.

## ŠTUDIJE O STAROSTI IN RASTI RIB V HRVAŠKI IHTIOLOŠKI ZNANOSTI

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### POVZETEK

*Študije o starosti in rasti ribjih vrst so ena glavnih analitičnih modelov za analizo dinamike izkoriščenih ribjih populacij. Avtor v tem članku ocenjuje že objavljene podatke o starostnih in razvojnih parametrih nekaterih ribjih vrst v vzhodnem Jadranu. Luske in otoliti so bila glavna kalcificirana tkiva, primerna za ugotavljanje starosti, medtem ko plavuti skorajda niso bile uporabljene. Starost in rast sta bili ugotovljeni za 17 ribjih vrst, kar je 14% od stodvajsetih komercialno zanimivih vrst. Glede na predstavljene rezultate pa lahko le zaključimo, da bo na področju ugotavljanja starosti in rasti komercialno zanimivih rib treba opraviti še veliko dela.*

**Ključne besede:** starost, rast, študije, hrvaška ihtiolška znanost

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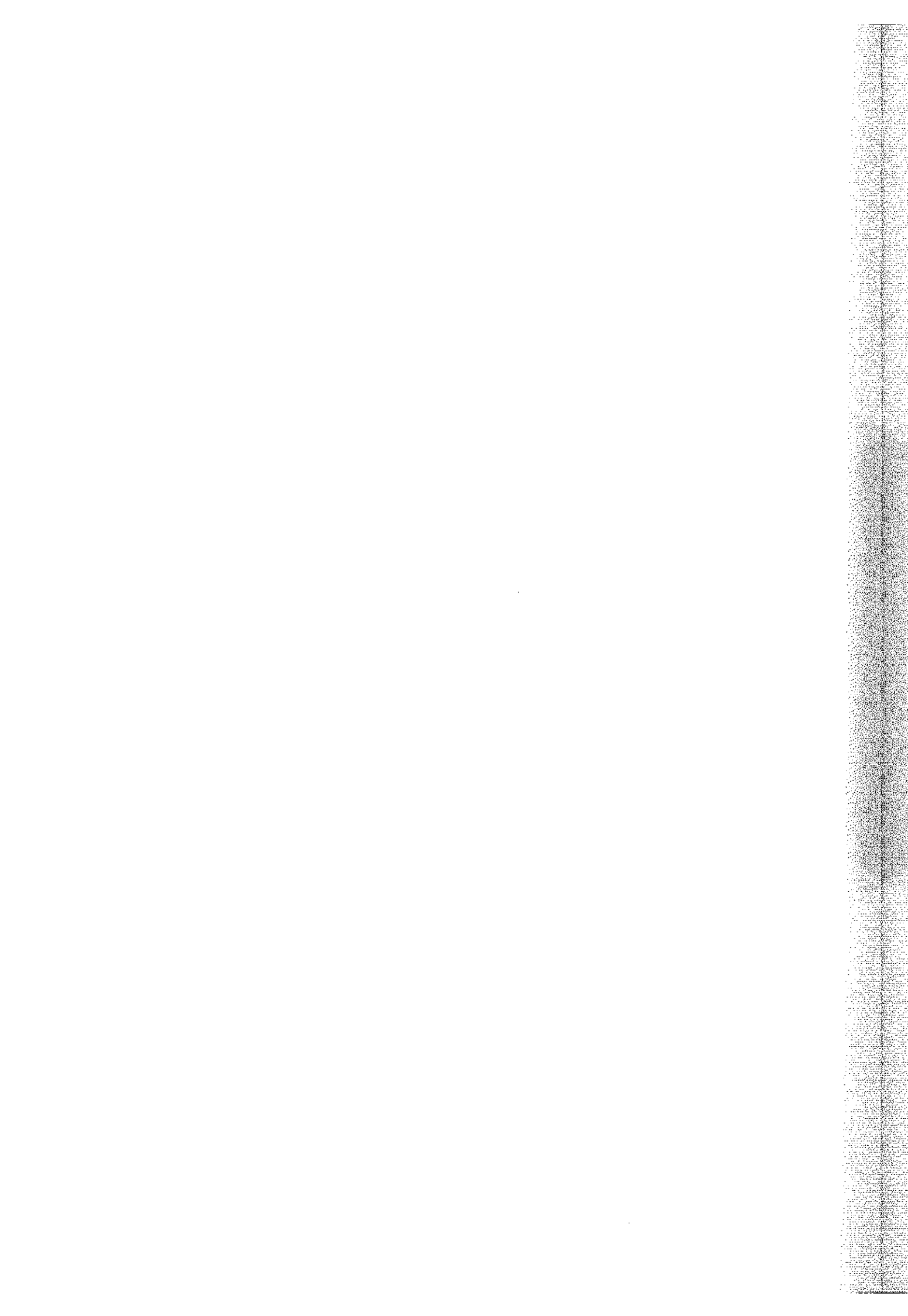
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**GEOLOGIJA IN PALEONTOLOGIJA**

**GEOLOGIA E PALEONTOLOGIA**

**GEOLOGY AND PALEONTOLOGY**





## $^{87}\text{Sr}/^{86}\text{Sr}$ ISOTOPIC CHARACTERISATION OF DOLINA SOILS AND FLYSCH ROCKS FROM TRIESTE AREA (NE ITALY)

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### ABSTRACT

$^{87}\text{Sr}/^{86}\text{Sr}$  isotopic analyses have been carried on some dolina soils, sandstones and marl (flysch) from Trieste area (NE Italy) in order to look for the parent material. By comparison of the obtained results, it is suggested that the main supplies to the genesis of these dolina soils are from the rocks constituting the flysch.

**Key words:**  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio, Trieste Karst, dolina soils, flysch

### INTRODUCTION

The Sr isotopes can be a powerful tool in studies of chemical weathering and soils genesis, reflecting the sources of Sr available during their formation. Isotopically distinct inputs from soil parent materials allow determination of the relative proportions of those materials entering or leaving a natural system.

This work gives a first Sr isotopic characterisation of the Trieste Karst soils, and of other sediments outcropping in the area, to evaluate the contribution of the latter in the soil genesis.

### GEOLOGICAL OUTLINES

In the Trieste Karst area (NE Italy), carbonates and different types of sandstones and marls of flysch rocks outcrop (Fig. 1). Cucchi *et al.* (1987) suggest to call the whole outcropping carbonate sequence as "Trieste Karst Limestone Formation" and to subdivide it in six provisional and informal members: Mt. Coste Mbr. (Early Cretaceous p.p.; limestones and lenses of dolostones), Rupingrande Mbr. (Albian p.p.- Cenomanian p.p.; dolostones and calcareous dolostones), Zolla Mbr. (Cenomanian p.p.-Early Turonian p.p.; limestones), Borgo Grotta Gigante Mbr. (Early Turonian p.p.- Senonian p.p.; limestones, lenses of breccia bianco-rosa and presence of vadose oolites-pisolites and *Mi-*

*crocodium*), M.te Grisa Mbr. (Paleocene p.p.; limestones and scattered breccia level), Opicina Mbr. (Paleocene p.p.-Early Eocene p.p.; limestones) (Fig. 2). The "Carbonate Trieste Karst Formation" is sometimes filled by bauxite near the K-T transition (Gregorič *et al.*, 1998), which speaks about moments of sub-aerial exposure. The stratigraphic sequence ended with the interbedded sandstones and marls of the Eocenic flysch.

### MATERIALS AND METHODS

The soils were sampled in dolinas by means of a hand drill to the depths between 50 and 130 cm. Sr isotopic compositions were measured on whole rock after dissolution of four dolinas soils samples, two unaltered sandstones and one unaltered marl by an HF-HNO<sub>3</sub>-HClO<sub>4</sub> mixture in Teflon<sup>®</sup> vials and standard ion-exchange chromatography using DOWEX AG 50 W X8 resin. Strontium isotopic ratios were measured on a multi-collector Finnigan MAT 262 mass spectrometer at Centro di Studio per il Quaternario e l'Evoluzione Ambientale (Rome; Italy). Replicate analyses of NBS-987 standard gave an average  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of 0.71025 (3), and no corrections were applied for instrumental bias.  $^{87}\text{Sr}/^{86}\text{Sr}$  values, as well as chemical data of the analysed samples (obtained by means of X-ray fluorescence spectrometer; Lenaz *et al.*, 1996), are reported in Tab. 1.

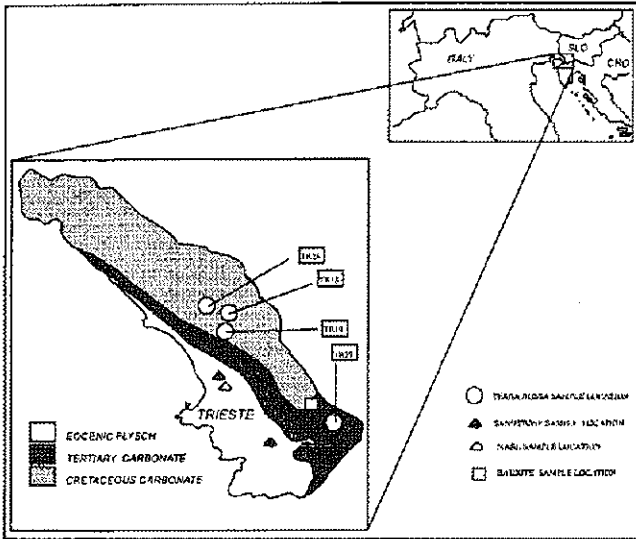


Fig. 1: Geological map of the Trieste area. Full triangle: sandstones; open triangle: marl; open circle: terra rossa; open square: bauxite (Gregorič et al., 1998) samples.

Sl. 1: Geološka karta tržaške pokrajine. Celotni trikotnik: peščenjaki; odprti trikotnik: lapor; odprti krog: terra rossa; odprti četverkotnik: primerki boksita (Gregorič et al., 1998).

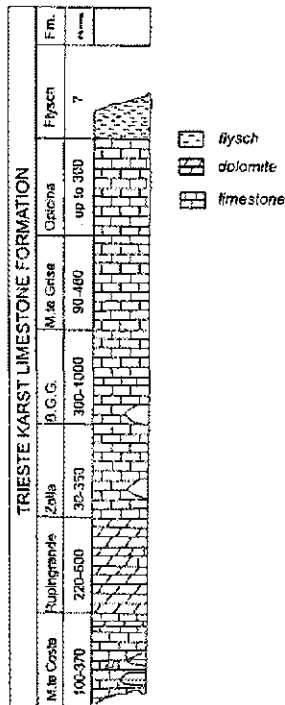


Fig. 2: Stratigraphic column of the Trieste Karst Carbonate Formation (modified from Cucchi et al., 1987). Sl. 2: Stratigrafski stolpec karbonatne formacije tržaškega Krasa (po Cucchi et al., 1987).

Tab. 1: Chemical analyses (oxides in wt. %, trace elements in ppm) and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of the studied samples; TR: terra rossa; S: sandstones; M: marl samples.

Tab. 1: Kemijske analize (oksidi in utežni odstotki slednih mineralov v ppm) in  $^{87}\text{Sr}/^{86}\text{Sr}$ -razmerje analiziranih vzorcev; TR: terra rosa; S: peščenjaki; M: primerki laporja.

|                                 | TR13           | TR19           | TR26           | TR39           | S1             | S2             | M1             |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| SiO <sub>2</sub>                | 46.76          | 52.03          | 50.09          | 54.78          | 56.74          | 44.20          | 20.20          |
| TiO <sub>2</sub>                | 1.08           | 1.09           | 1.23           | 1.15           | 0.58           | 0.32           | 2.63           |
| Al <sub>2</sub> O <sub>3</sub>  | 21.59          | 19.35          | 19.41          | 18.24          | 8.98           | 5.74           | 39.86          |
| FeO                             | 0.71           | 7.71           | 1.98           | 2.05           | 2.98           | 2.30           | 18.05          |
| Fe <sub>2</sub> O <sub>3</sub>  | 10.56          | n.d.           | 7.22           | 5.56           | n.d.           | n.d.           | n.d.           |
| MnO                             | 0.18           | 0.18           | 0.17           | 0.14           | 0.25           | 0.12           | 0.01           |
| MgO                             | 1.59           | 1.97           | 1.80           | 1.86           | 1.84           | 1.36           | 0.14           |
| CaO                             | 1.01           | 2.22           | 1.57           | 1.37           | 15.78          | 27.67          | 0.24           |
| Na <sub>2</sub> O               | 0.42           | 0.71           | 0.48           | 0.83           | 1.35           | 0.70           | 0.08           |
| K <sub>2</sub> O                | 2.17           | 2.14           | 1.81           | 2.19           | 1.26           | 0.67           | 0.09           |
| P <sub>2</sub> O <sub>5</sub>   | 0.10           | 0.17           | 0.13           | 0.16           | 0.06           | 0.01           | 0.04           |
| L.O.I.                          | 14.64          | 12.33          | 14.66          | 12.08          | 10.10          | 16.87          | 18.43          |
| SUM                             | 100.81         | 99.90          | 100.55         | 100.41         | 99.92          | 99.96          | 99.77          |
| Cr                              | 215            | 195            | 204            | 194            | 268            | 133            | 168            |
| Ni                              | 146            | 103            | 118            | 84             | 54             | 48             | 118            |
| Rb                              | 191            | 152            | 146            | 132            | 45             | 27             | 165            |
| Sr                              | 87             | 105            | 106            | 107            | 232            | 404            | 239            |
| Nb                              | 22             | 20             | 20             | 17             | 8              | 5              | 9              |
| Zr                              | 291            | 328            | 306            | 304            | 145            | 120            | 130            |
| Y                               | 51             | 51             | 50             | 49             | 31             | 23             | 27             |
| Ba                              | 149            | 526            | 448            | 492            | 149            | 132            | n.d.           |
| La                              | 21             | 69             | 66             | 58             | 22             | 19             | n.d.           |
| Ce                              | 42             | 142            | 161            | 137            | 41             | 37             | n.d.           |
| Nd                              | 21             | 62             | 62             | 55             | 21             | 17             | n.d.           |
| $^{87}\text{Sr}/^{86}\text{Sr}$ | 0.71833<br>(1) | 0.71762<br>(1) | 0.71594<br>(1) | 0.71847<br>(1) | 0.71341<br>(3) | 0.71523<br>(2) | 0.72241<br>(2) |

DISCUSSION AND CONCLUSIONS

$^{87}\text{Sr}/^{86}\text{Sr}$  isotopic data have been compared to one another, to limestone values taken from literature (Hess et al., 1986), and to the  $^{87}\text{Sr}/^{86}\text{Sr}$  value of a KT bauxite outcropping near Padriciano (Gregorič et al., 1998). These findings reveal that dolina soils have  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios ranging from 0.7159 (1) to 0.7183 (1), with a mean value very close to that of the typical terrigenous sedimentary materials of the Mediterranean area (about 0.717; Dasch, 1969). These data differ not only from the Cretaceous and Tertiary limestone data (0.707 - 0.708; Hess et al., 1986; Javoy & Courtillot, 1989), but also from the  $^{87}\text{Sr}/^{86}\text{Sr}$  values of the bauxite at the K-T transition near Padriciano (0.7080 ± 1; Gregorič et al.,

1998). This happens because all the sediments of the carbonate sequences, and the sediments related to sub-aerial exposure interbedded in, were re-equilibrated in seawater conditions.

Samples of flysch show  $^{87}\text{Sr}/^{86}\text{Sr}$  values of 0.7134 (3) - 0.7152 (2) and 0.7220 (2) for sandstones and marl, respectively. The values of terra dolina soils are included in this range and are intermediate with respect to the ones obtained for sandstone and for marly components of the flysch itself.

In Fig. 3 the flysch and the dolina soils in a  $\text{K}_2\text{O}$  vs.  $^{87}\text{Sr}/^{86}\text{Sr}$  diagram are represented. The samples show a good positive correlation and are best approximate by a second-degree polynomial function ( $R^2=0.97$ ) evidencing that dolina soils could be generated by a mixing of sandstones and marls. In the carbonate K is under 66 ppm (Comin Chiamonti *et al.*, 1982) and the value of  $^{87}\text{Sr}/^{86}\text{Sr}$  is lower than 0.708 because this is the value of the pre-Tertiary sea (Hess *et al.*, 1986). This fact seems to exclude an important contribution of  $^{87}\text{Sr}/^{86}\text{Sr}$  from

carbonate sequence and bauxite level because it will have lowered the isotopic ratio. Moreover, it is possible to notice that TR sample overlying carbonate rocks of different age, TR39 and TR13, have the same  $^{87}\text{Sr}/^{86}\text{Sr}$  isotopic ratio.

In conclusion, the  $^{87}\text{Sr}/^{86}\text{Sr}$  data seem to confirm that the flysch components are the best candidate to explain the dolina soils source. In fact previous mineralogical studies on the same soils (Lenaz *et al.*, 1996) and previous comparisons of the Cr-spinel crystal-chemistry from dolina soils with the one from the flysch (Carbonin *et al.*, 1999), indicate the main source of these soils in the flysch material.

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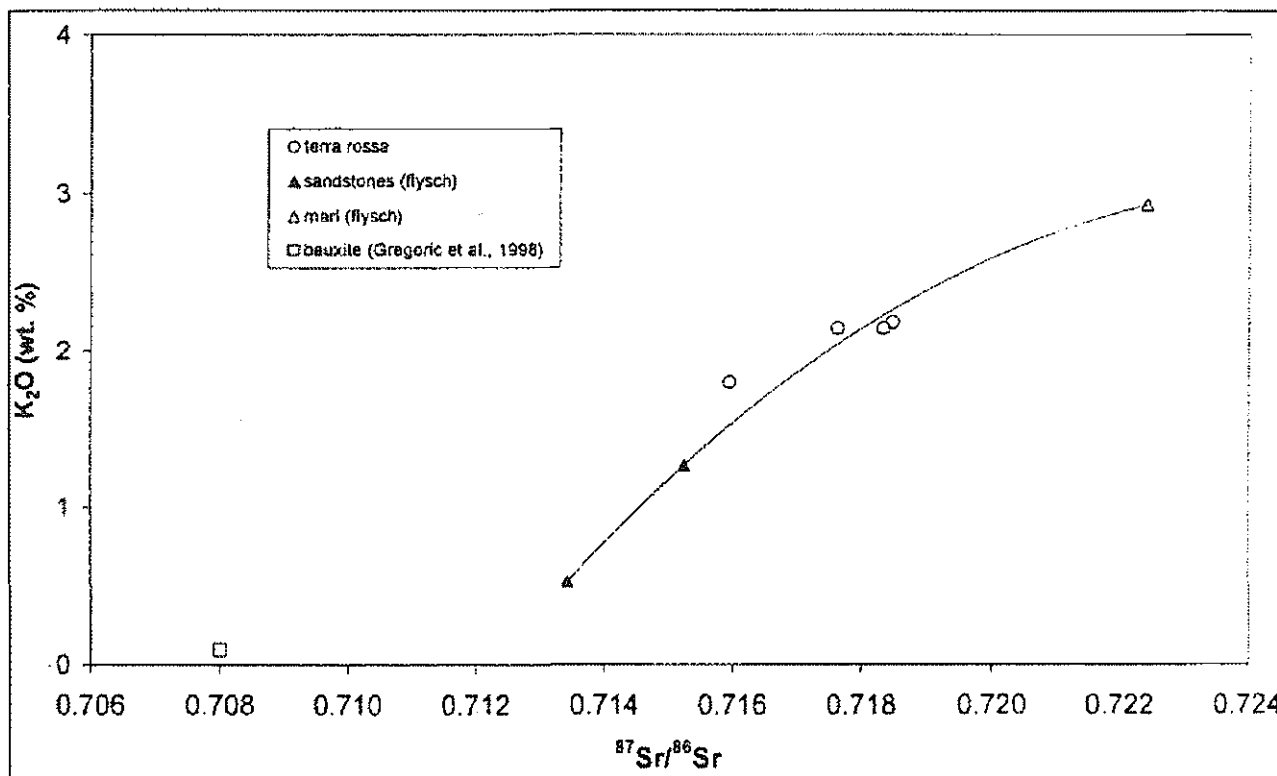


Fig. 3:  $\text{K}_2\text{O}$  vs.  $^{87}\text{Sr}/^{86}\text{Sr}$  diagram; symbols as in Fig. 1.  
 Sl. 3: Diagram  $\text{K}_2\text{O}$  proti  $^{87}\text{Sr}/^{86}\text{Sr}$ ; simboli kot na sl. 1.

$^{87}\text{Sr}/^{86}\text{Sr}$  IZOTOPSKA KARAKTERIZACIJA PRSTI DOLIN IN FLIŠNIH PLASTI IZ OKOLICE TRSTA (SV ITALIJA)

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## POVZETEK

Da bi ugotovili izvirne kamnine prsti v nekaterih dolinah v okolici Trsta, smo izvedli  $^{87}\text{Sr}/^{86}\text{Sr}$ -izotopske analize teh prsti, flišnih pesčenjakov in laporjev. Ob primerjavi dobljenih rezultatov domneva, da gre nastanek prsti v dolinah pripisati predvsem kamninam, ki sestavljajo tamkajšnji fliš.

**Ključne besede:** razmerje  $^{87}\text{Sr}/^{86}\text{Sr}$ , tržaški Kras, prst, "doline", fliš

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## UPPER CRETACEOUS FLORA OF SLOVENIA

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## ABSTRACT

*Plated and laminated limestones with chert of the Trieste-Komen plateau occur as a special facies within different Upper Cretaceous platform sediments. In the present state of study they are ranged as the Komen and the Tomaj Limestones. In both limestone types many fossil plants were collected. The Slovenian flora differs from all known Upper Cretaceous floras of Europe in the predominance of conifers, while angiosperms are in the minority. In this paper, plants from ten localities are documented that have not been present till now in the map of the Upper Cretaceous floras of Europe.*

**Key words:** flora, Upper Cretaceous, Dinaric carbonate platform, Trieste-Komen plateau, Slovenia

## INTRODUCTION

The finds of megaplant fossils of the Upper Cretaceous platy and laminated limestones of the Trieste-Komen plateau have been poorly known. In spite of numerous specimens from the Komen Limestone that have been housed for decades in the Natural History Museum of Slovenia in Ljubljana and in the Museo Civico di Storia Naturale in Trieste (Italy), plant fossils attracted little attention compared with many vertebrate finds, especially fishes and reptiles reported already by Gorjanović-Kramberger (1895). The megaplants of the Santonian-Campanian Tomaj Limestone have not been known until recently. Yet, they were only mentioned in the journal *Annales* in the paper on the find of the ray *Rhinobatos* (Jurkovšek & Kolar-Jurkovšek, 1995). The Maastrichtian plants of the Liburnian Formation were partly described by Stache (1889).

A new locality appears on the map of the Upper Cretaceous floras of Europe in the very middle of the European continent. Upper Cretaceous plants in Slovenia, widens seriously our knowledge about Cretaceous floras of Europe. This flora differs from all known Upper

Cretaceous floras of the region in the predominance of conifers while in other localities of Europe, Africa and Near East in coeval floras the main role belongs to angiosperms, where conifers are in the minority or are completely absent. In the studied collection, the angiosperms are represented by small quantity of small isolated leaves. Slovenian conifers are very special. We still could not find similar species in coeval deposits of Europe. Probably there are new conifer species or even genus in the flora under consideration. Their general habitus recalls more ancient types of conifers.

Unfortunately, the preservation of imprints is not good enough, cuticles are absent. For monographic study more time and material are needed. In spite of this it seems advisable to publish preliminary conclusions of our study: to give preliminary determinations of plants, together with their photographs, to present general review of the Slovenian Upper Cretaceous flora and compare it with coeval floras of the adjacent areas.

Studied megaplant specimens are housed in the collections of the Natural History Museum of Slovenia in Ljubljana, the Museo Civico di Storia Naturale di Trieste (Italy) and the paleontological collection of Bogdan

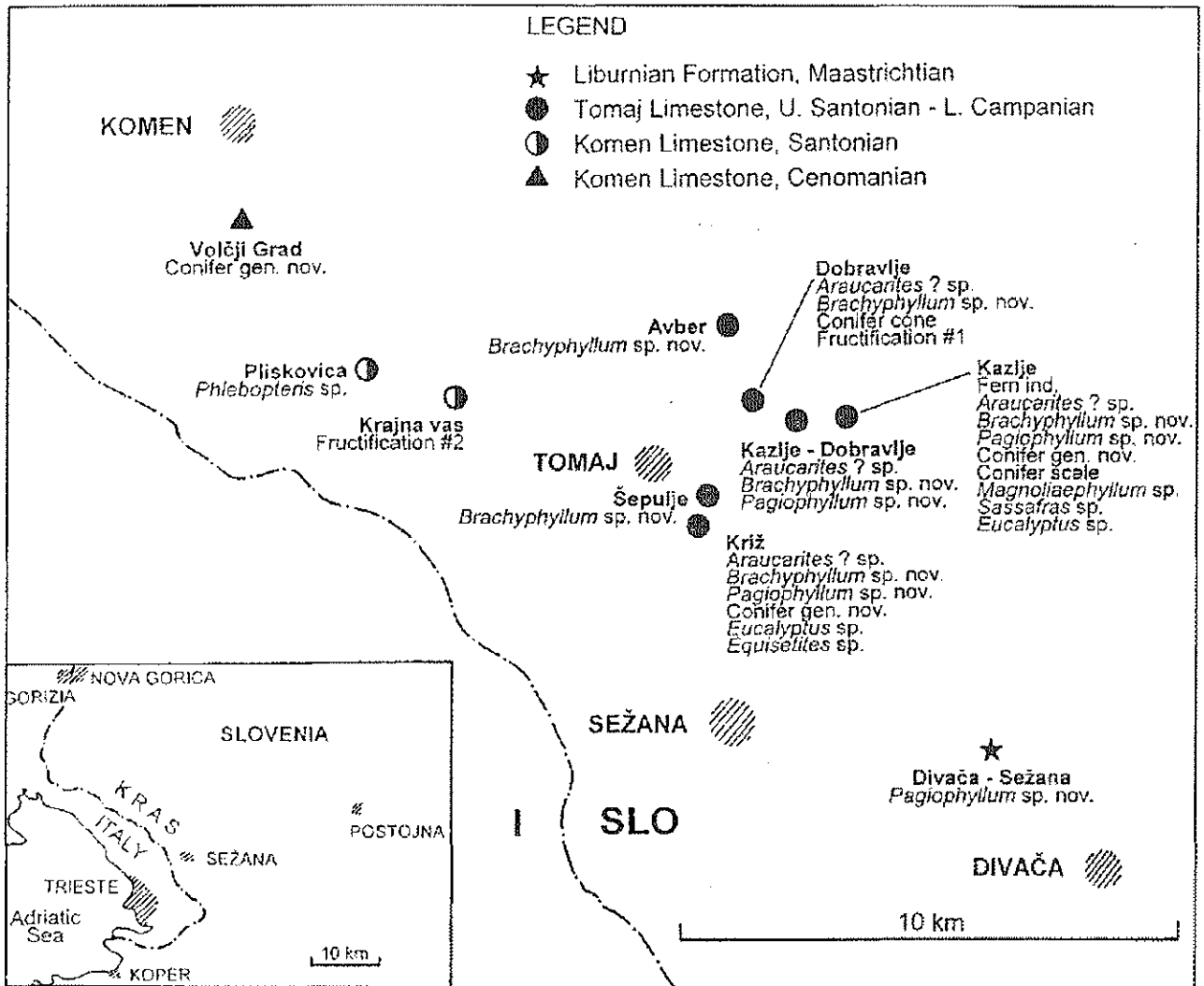


Fig. 1: Geographic sketch map showing distribution of fossil flora at different localities.  
 Sl. 1: Geografska skica z razširjenostjo fosilne flore v različnih nahajališčih.

Jurkovšek and Tea Kolar-Jurkovšek at Dol pri Ljubljani (Slovenia) that has been in accordance with the current legislation registered with the Ministry of Culture of the Republic of Slovenia and the Natural History Museum of Slovenia.

**Abbreviations:**

- PMS - Prirodoslovni muzej Slovenije / Natural History Museum of Slovenia, Ljubljana
- TS - Museo Civico di Storia Naturale di Trieste, Italy,
- BJ - Paleontological collection of Bogdan Jurkovšek and Tea Kolar-Jurkovšek, Dol pri Ljubljani.

**LATE CRETACEOUS BITUMINOUS LIMESTONES OF THE TRIESTE-KOMEN PLATEAU AND STRATIGRAPHIC POSITION OF THE STUDIED PLANT FOSSILS**

Kras in strict tectonic sense can be defined as the

Trieste-Komen plateau or the Komen thrust sheet (Fig. 1), but in a wider geotectonic sense Kras belongs to the extensive Outer Dinarides. It is characterised by shallow water platform carbonates and occurrence of black platy and laminated bituminous limestones with chert that locally comprise also plant fossils. They appear within different Upper Cretaceous formations from Cenomanian to Campanian. On the geological map of the southern part of the Trieste-Komen plateau 1 : 50,000 (Jurkovšek et al., 1996) these rocks are incorporated in two members, the Komen and the Tomaj Limestones. The older member is the Komen Limestone that appertains to the Povir, Repen and Sežana Formations; the younger member is the Santonian-Campanian Tomaj Limestone of the Lipica Formation (Fig. 2).

Due to the common lithological similarities of bituminous platy and laminated limestones with chert of various formations, first of all those characteristics that



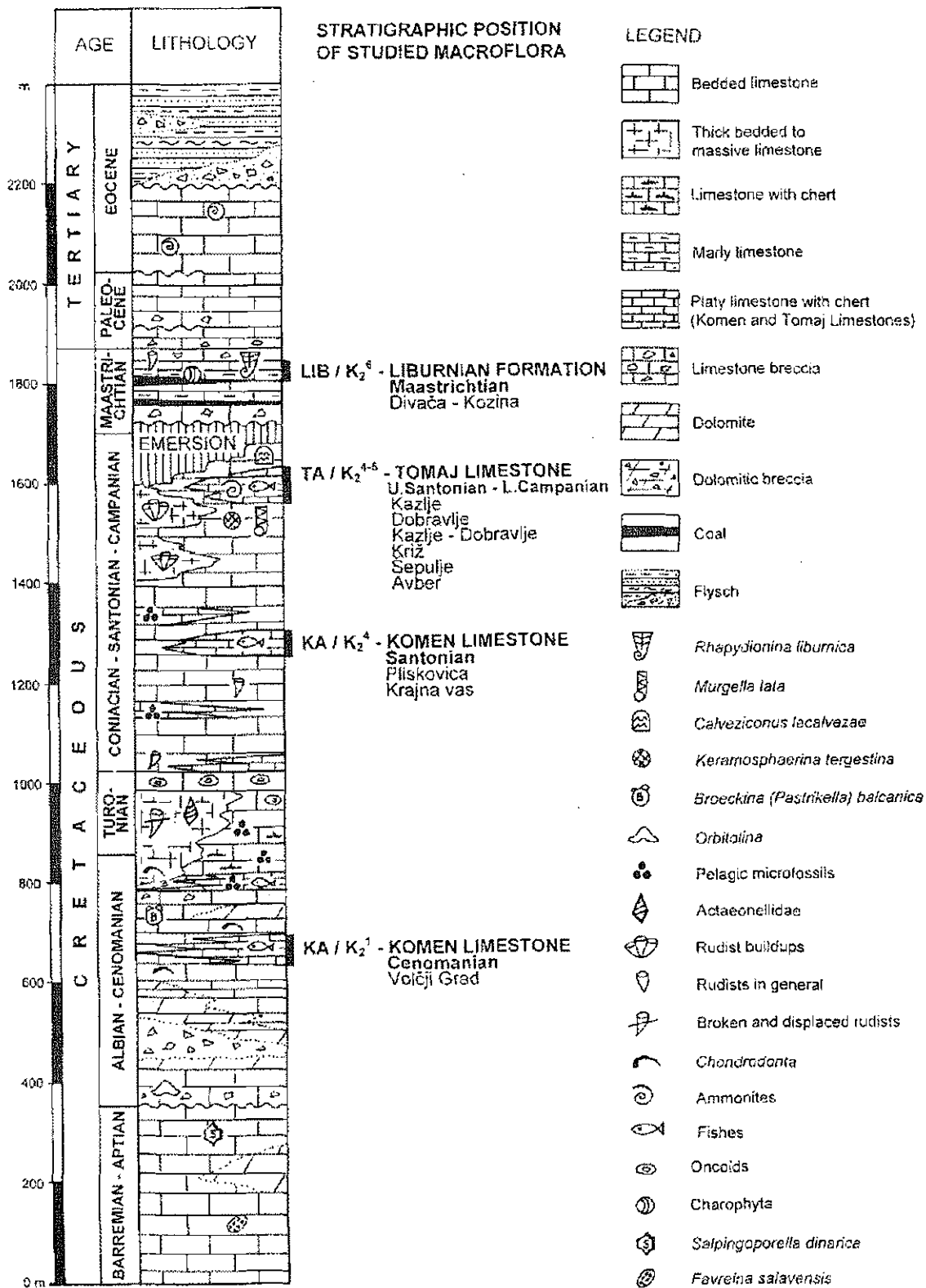


Fig. 2: Stratigraphic column of the Cretaceous beds of the Trieste-Komen plateau with marked positions of studied flora.

Sl. 2: Stratigrafski stolpec krednih plasti Tržaško-komenske planote z označenimi položaji raziskane flore.

point out to different modes and areas of their origin on the carbonate platform were considered during the geological mapping of the northern part of the Trieste-Komen plateau.

Based on the studies of depositional environments and mechanisms of the modern marine carbon rich black shales, Arthur and Sageman (1994) summarised that their deposition can take place in five major modern marine environments:

- deep, enclosed basin,
- deep borderland basin,
- continental slope, zone of "upwelling",
- shallow stratified basin,
- coastal / intertidal zone.

Šribar (1995) was of the opinion that due to the position on the carbonate platform, only the areas of "upwelling" and coastal intertidal zones were adequate in the case of southwestern Slovenia for the formation of the Upper Cretaceous bituminous limestones.

Komen Limestone (from the vicinity of Komen) has been recently often discussed as evidence for the second oceanic event (OAE 2). Based on comparison of facies on the Dinaric-Adriatic platform and conditions in a wider Mediterranean area, Jenkyns (1991) concluded that during the Cenomanian-Turonian there was a particularly thick column of anoxic water. In the Umbria-Marche basin it resulted in a deposition of the Bonarelli Level. OAE 2 consists of more anoxic events and the main (Bonarelli Level) is preceded by several thinner anoxic levels (Montanari *et al.*, 1995). Oceanic anoxic events influenced the sedimentary conditions of the Dinaric carbonate platform of southwest Slovenia. They were decisive mainly for the deposition of the Komen Limestone within the upper part of the Cenomanian Povir Formation and the Cenomanian-Turonian Repen Formation. Indeed, similar anoxic conditions could exist also in enclosed lagoons where high biological production and oxygen minimum caused a deposition of carbon rich beds.

Precise interpretation of the origin of the Tomaj Limestone remains not fully understood, for the connection with the eustatic sea level rise in this part of Tethys has still not been explained. According to Šribar (1995), the authigen formation of anoxic conditions seems to be likely. Based on the presence of alodapic limestones, a somewhat deeper environment of the deposition of these beds was presumed by Ogorelec and associates (1987). In contrast to the Komen Limestone, there have never been any indications of intertidal conditions in the Tomaj Limestone (Jurkovšek *et al.*, 1996). Pelagic micro- and megafossils with prevailing ammonites indicate a good connection of the sedimentary environment with open sea. Summesberger and associates (1996a, 1996b, 1999) reported on numerous ammonites with preserved body chambers, aptychi partially in situ and their rollmarks, which means that in the water column above

the seafloor with anoxic conditions allowed the existence of nektonic and planktonic organisms. At certain levels, a mass mortality with fishes is evidenced and it is connected with mixing of well-stratified water in a lagoon. Based on hitherto knowledge, a strong influence of pelagial on the Tomaj Limestone can be linked also to the sea level rise and the second pelagic episode during the Late Santonian-Campanian that reached its maximum in the Campanian (Haq *et al.*, 1987; Gušić & Jelaska, 1990; Kolar-Jurkovšek *et al.*, 1996). A rich macroflora is present at the studied localities of the Tomaj Limestone and it was derived from the land that as early as in the Late Santonian began to rise up south of the Tomaj lagoon (Pleničar & Jurkovšek, 1997a, 1997b).

Organical-chemical parameters of the Komen and Tomaj Limestones are similar. However, the average value of the organic matter ( $C_{org}=0.48\%$ ) is in general higher in the Tomaj Limestone than in the Komen Limestone. That ranks the Tomaj Limestone to the lowermost range of hydrocarbon potential source rocks (Ogorelec *et al.*, 1996). In comparison with the Komen Limestone it contains more organic matter of marine origin (alginite), while in the Komen Limestone there prevails the organic matter of terrestrial origin (lignin-huminite type).

The studied museal specimens of the Upper Cretaceous flora housed in the Natural History Museum of Slovenia in Ljubljana and the Museo Civico di Storia Naturale di Trieste (Italy) were ranged into different horizons of the Komen Limestone and in the Tomaj Limestone according to the recorded data (Fig. 2). Samples from Volčji Grad were collected in the Komen Limestone of the Povir Formation and are Middle to Late Cenomanian in age. The plant fossils of Pliskovica and Krajna vas were recovered from the Komen Limestone of the Santonian part of the Sežana Formation. All samples including samples from the Paleontological collection of Bogdan Jurkovšek and Tea Kolar-Jurkovšek that were collected in the areas of Kazlje, Dobravlje, Šepulje and Križ are ranged in the Upper Santonian-Campanian Tomaj Limestone of the Lipica Formation. The specimen from the Divača-Sežana motorway section was sampled in the Maastrichtian part of the Liburnian Formation just above a thin coal bed.

## PALEONTOLOGICAL PART

### Systematic composition of the Upper Cretaceous Flora of Slovenia

Type **Sphenopsida**  
 Class **Equisetinae**  
 Order **Equisetales**  
 Family **Equisetaceae**  
*Equisetites* sp.

Type **Pteropsida**Class **Filices**

## Order Filicales

## Family Matoniaceae

*Phlebopteris* sp.Class **Gymnospermae**

## Order Coniferales

## Family Araucariaceae

*Araucarites* ? sp.

## Family Araucariaceae ?

*Brachyphyllum* sp. nov.*Pagiophyllum* sp. nov.

## Family Taxodiaceae

*Sequoia* sp.

## Family unknown.

## Conifer gen. nov.

## Conifer cone

## Conifer scale

Class **Angiospermae**

## Order Magnoliales

## Family Magnoliaceae

*Magnoliaephyllum* sp.

## Order Laurales

## Family Lauraceae

*Sassafras* sp.

## Order Myrtales

## Family Myrtaceae

*Eucalyptus* sp.

## Undeterminable fructifications

**Sphenopsida**

Only one incomplete specimen with two rests of stems is present in our collection (Pl. 1, Figs. 2a, 2b). Because of its preservation it is impossible to see if there are alternating ribs or not. So determination as *Equisetites* is conditional and it cannot be excluded that these remains belong to such similar genera as *Calamites*, *Neocalamites* etc.

**Filicales**

Ferns in our collection are represented by two specimens, one of which is indeterminable. The second one (Pl. 1, Figs. 1a, 1b, 1c) is considered to be *Phlebopteris* without species determination. On photos one can see sterile leaves with very characteristic venation (Pl. 1, Figs. 1a, 1b) and fertile ones (Pl. 1, Fig. 1c) as well.

**Coniferales**

Some conifer scales from different localities have been determined as *Araucarites* with the question mark (Pl. 11, Figs. 1-6), but they should certainly be additionally investigated.

Relatively large leafy twigs are the basis of our collection. The majority of them are considered to be *Brachyphyllum* (Pl. 2, Figs. 1-6, Pl. 3, Figs. 1-5) and *Pagiophyllum* (Pl. 4, Figs. 1-6, Pl. 5, Figs. 1-3, Pl. 6, Figs. 1-2). The two above-mentioned genera differ from each other by the relations of the free part of the leaf and its attached part: the first has leaves attached to rachis by all their length. In the second a large part of the leaf is free. In our material there are many intermediate forms, so it is difficult to find a boundary between genera and is merely conditional. Only after monographic study it will be possible to give more exact determinations and to compare Slovenian species with the species from different regions. Nevertheless, at the first stage of the study this is not so important, as both belong to the same group of conifers and can be used as homogenous flora.

The genus *Brachyphyllum* is known from the Upper Cretaceous floras, e.g. from Daralagez in the Transcaucasus and from Lebanon. But it is more widely distributed in the Lower Cretaceous (Portugal, West Kazakhstan, Primorye, India), Jurassic (Yorkshire, Central Europe, France, North Italy, Caucasus, Georgia, less in Central Asia and India) and Triassic (Donbass, Central Asia, Pamirs, Vietnam).

In the Trieste Museum of Natural History there are several very interesting specimens from the locality of Volčji Grad (Pls. 7, 8, 10). They are relatively large twigs compactly covered with leaves or scales as in *Brachyphyllum*. In the upper part, the twigs are dichotomizing several times. In the lower part of rachis places of deciduous twigs are seen. One plant from Križ (Pl. 9, Figs. 1a, 1b, 1c) also belongs to this group. According to the number of dichotomy and thickness of twigs of the second order, these plants can be divided into two groups (two species of a new genus?). Specimens on plates 7, 8 and 9 belong to the former one, specimens on plate 10 to the latter. In our list of fossil species they appear under the name "Conifer gen. nov".

There are seven specimens of this kind in the collection, and five of them were found at a single locality - Volčji Grad. This locality produced only this kind of plant remains.

Conifer twigs resembling the above mentioned plants due to their habitus and size are described and figured from the Cretaceous of Bohemia, Portugal and northern France. But none can be identified with Slovenian remains.

**Conifer cone and scales**

There are remains of isolated conifer scales and one full conifer cone (Pl. 11) in the Slovenian collection. At this stage of the study we prefer not to determinate them as yet.

**Angiosperms**

Among 61 specimens of fossil plants in our collection there are only nine small isolated leaves of angiosperms, which could be due to the insufficient material determined only approximately. In our opinion they belong to *Magnoliaephyllum* (Pl. 12, Figs. 1-3), *Sassafras* (Pl. 12, Fig. 10) and *Eucalyptus* (Pl. 12, Figs. 4-8).

**Undeterminable fructifications**

Two very interesting imprints were found at the localities of Dobravlje (Pl. 12, Fig. 12) and Krajna vas (Pl. 12, Fig. 11). They are probably fructifications. We do not exclude that they belong to Caytoniales, but would rather not determine them as yet.

Thus, among 61 imprints of the Upper Cretaceous plants there are 46 conifers, 9 angiosperms, two ferns and one horsetail and two fructifications of unknown affinity. This means that conifers constitute more than a half of the collection - 77%, angiosperms - 17%. Conifers and angiosperms jointly cover 94% of the entire material (Fig. 3).

Conifers are of an old appearance, including those that have been determined as *Brachyphyllum* and *Pagiophyllum*. Remains that have been determined as "Conifer gen. nov." generally resemble the genus *Voltzia*, which was widely distributed in Europe during the Triassic. In order to compare Slovenian fossils with *Voltzia* we would require not only additional and more abundant material from Slovenia but also a revision of the last genus. This has still not been done.

**Local geography and geology. Localities.**

Distribution of fossil plants at different localities; the number opposite the species name indicates the number of imprints of the species.

- Volčji grad, Cenomanian:** Conifer gen. nov. - 5
- Pliskovica, Santonian:** *Phlebopteris* sp. - 1
- Krajna vas, Santonian:** Fructification #2 - 1
- Avber, Santonian-Campanian:** *Brachyphyllum* sp. nov. - 2
- Dobravlje, Santonian-Campanian:** *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 6; Conifer cone - 2; Fructification #1 - 1
- Kazlje-Dobravlje, Santonian-Campanian:** *Equisetites* sp. - 1; *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 2; *Pagiophyllum* sp. nov. - 3

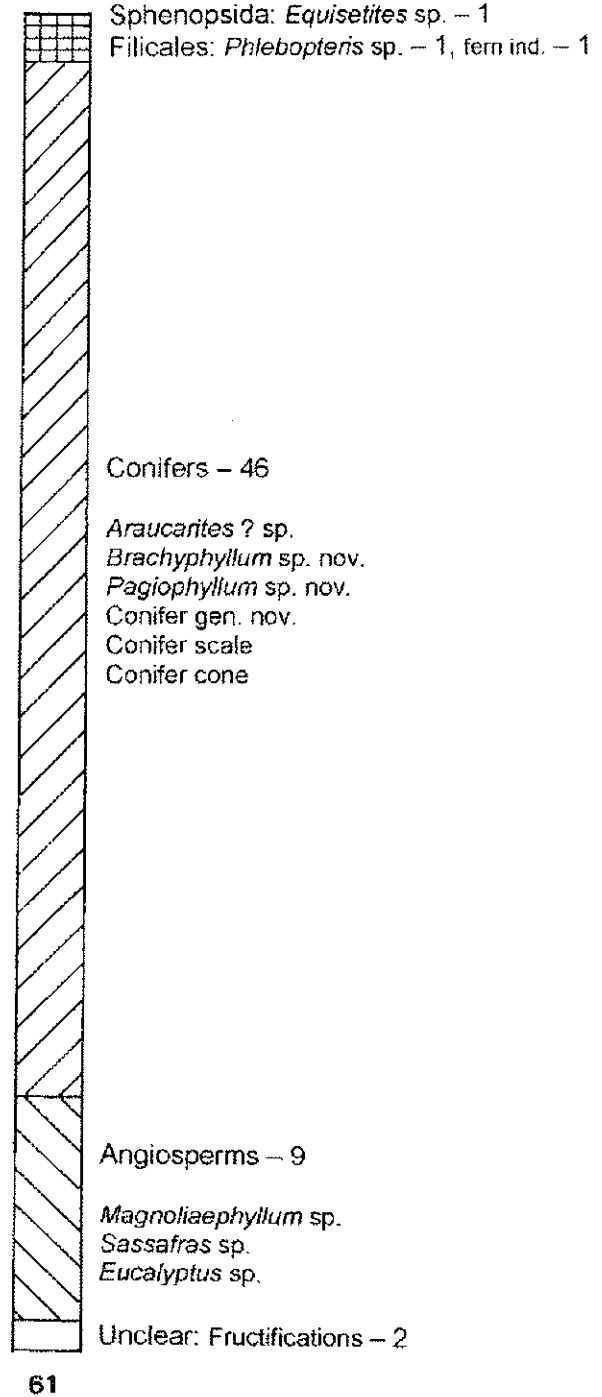


Fig. 3: Relative role of the main fossil plant groups in the Upper Cretaceous floras of the Trieste-Komen plateau. The whole number of imprints is given under the column, the number of imprints of each group is shown by the name of the group.

Sl. 3: Relativna vloga najvažnejših skupin fosilnih rastlin v zgornjekredni flori Tržaško-komenske planote. Celotno število odtisov je podano pod stolpcem, število odtisov vsake skupine je prikazano pri imenu skupine.

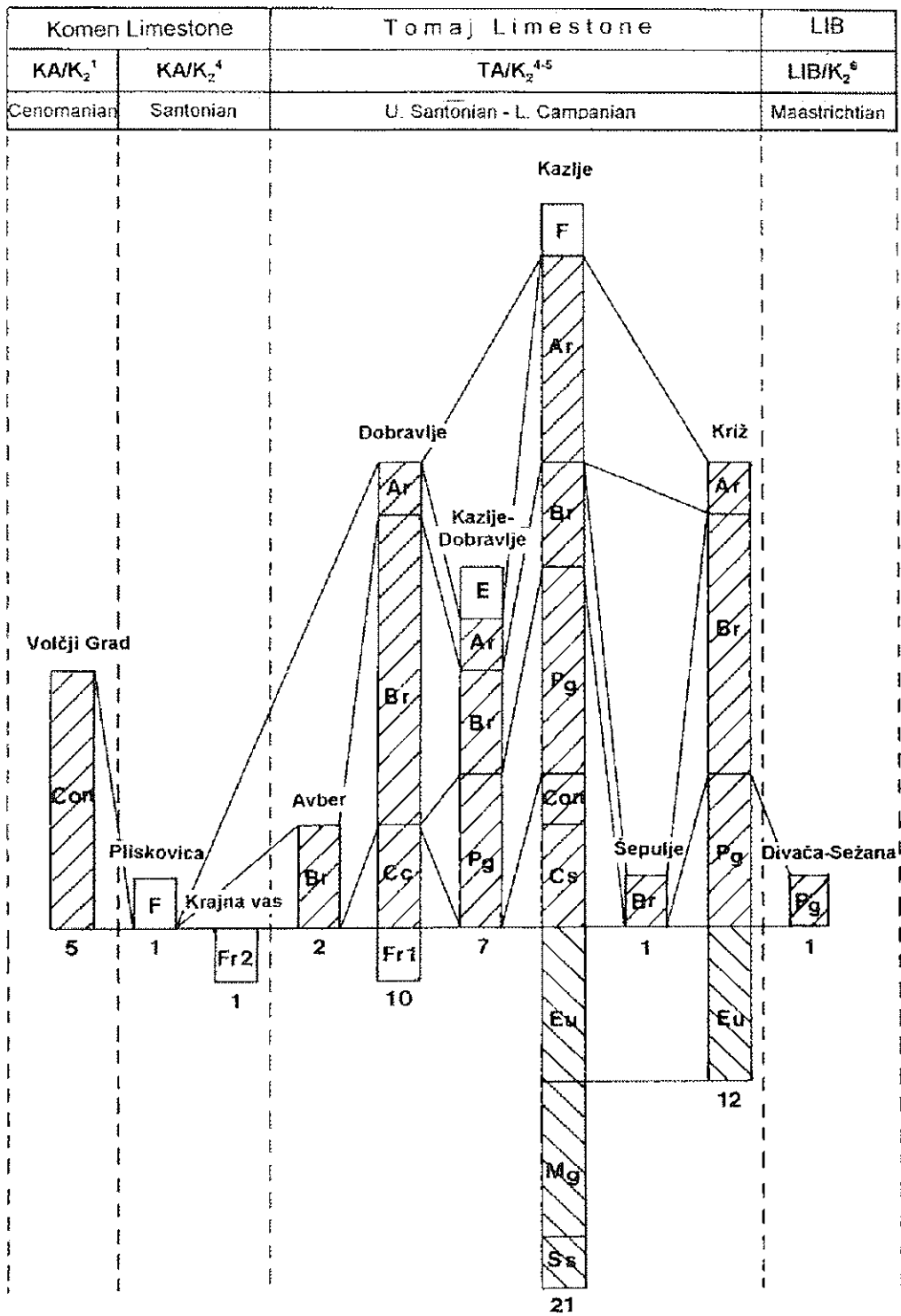


Fig. 4: Systematics of the Upper Cretaceous plants of the Trieste-Komen plateau at different localities, the number of accounted imprints is given under the columns:

Sl. 4: Sistematika zgornjekrednih rastlin Tržaško-komenske planote po nahajališčih, število odtisov je podano pod stolpcem:

E - Equisetites, F- ferns, Ar - Araucarites, Br - Brachyphyllum, Pag - Pagiophyllum, Con - conifer gen. nov., Cc - conifer cone, Cs - conifer scale, Eu - Eucalyptus, Mg - Magnoliaephyllum, Ss - Sassafras, LIB - Liburnian Formation.

**Kazlje, Santonian-Campanian:** Fern ind. - 1; *Araucarites* ? sp. - 4; *Brachyphyllum* sp. nov. - 2; *Pagiophyllum* sp. nov. - 4; Conifer gen. nov. - 1; Conifer scale - 2; *Magnoliaephyllum* sp. - 3; *Sassafras* sp. - 1; *Eucalyptus* sp. - 3

**Šepulje, Santonian-Campanian:** *Brachyphyllum* sp. nov. - 1

**Križ, Santonian-Campanian:** *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 5; *Pagiophyllum* sp. nov. - 2; Conifer gen. nov. - 1; *Eucalyptus* sp. - 3

**Divača-Sežana, Maastrichtian:** *Pagiophyllum* sp. nov. - 1

In figure 4, distribution of species at different localities is shown graphically.

### Comparison with adjacent Cretaceous floras

We still could not have found with certainty any analogues of Slovenian plants in coeval floras. We could not find any similar Upper Cretaceous flora - neither in the Northern Mediterranean (Europe), nor in the Southern Mediterranean (Near East and Northern Africa). No flora has so many conifers (and special ones) and so few other plants (Dobruskina, 1996, 1997).

On the other hand, in adjacent areas, abundant conifers existed in the Triassic (NE Italy, Slovenia, Austria, Switzerland, Germany, France), Jurassic (Italy) and perhaps in the Cretaceous of Northern Italy. According to the finds of the fossil woods, conifer forests were widely distributed in Israel and Lebanon (Dobruskina & Philippe, 1996).

Figure 5 shows Upper Cretaceous localities in Europe and in the Transcaucasus. The nearest to the Trieste-Komen plateau are Hvar (Kerner, 1895) and Friuli (Pinna, 1993). In spite of the insufficient data about age and composition of these two floras, it is possible to say that they do differ from Slovenian flora. From Lesina 6 ferns, 9 cycadophytes, 6 conifers and 5 angiosperms were figured. Neither plants themselves nor relations between the main plant groups are the same as in Slovenia. From "Vernasso nel Friuli" only several small imprints of conifers - different from Slovenian - were figured.

Regarding the still unstudied flora of Gruenbach in Niederoesterreich there are, according to the list in Guidebook (Summesberger, 1997) five ferns, two gymnosperms and 25 angiosperms. This is quite common for the majority of the Upper Cretaceous floras in Europe but different from Slovenian.

The most famous and abundant among the Upper Cretaceous floras of Europe is the Cenomanian flora of Bohemia and Moravia. It was first described as early as in 1881-1887 by Velenovsky. Now it is being intensively studied. Only the list of references covers three pages (if we have all of them) and consists of 14 publications of Velenovsky (including Velenovsky & Vinclár

and at least of 26 publications of other paleobotanists (Bayer, Heer, Elkund, Hlůstik, Knobloch, Kvacek Z., Kvacek J., Nemejc). But in spite of the abundance of publications, localities and specimens, there has still been no updated review of the Bohemian Upper Cretaceous flora. It is difficult to determine the dominant plant group, because there are many ferns, many cycadophytes, enough conifers, and many angiosperms. Amongst conifers we did not find forms similar to the Slovenian representatives of this group.

It seems that more features that are common with ours may be in the flora of Daralagez (Transcaucasus), but very few plants have been figured and briefly described (Palibin, 1937). In his conclusions, Palibin refers to the abundance of conifer forests and leafy forests in the Upper Cretaceous of Daralagez. At the same time he emphasises a great similarity of Daralagez flora to the Bohemian flora. One specimen - determined by Palibin as *Widdringtonites* - slightly resembles our "conifer gen. nov", but is much smaller.

Another similar twig (and again much smaller) was figured by Teixeira (1948) from Portugal as *Sphenolepidium*. In general, the Upper Cretaceous flora of Portugal is not similar to ours, for it consists mainly of angiosperms.

Lower Cretaceous conifers from Northern Italy were figured in the large volume of G. Pinna with reference to Bozzi L. La flora cretacea di Vernasso nel Friuli - *Bullettino della Societa Geologica Italiana*, vol.10, Roma, 1891. More up-to-date information on plants and localities is still not at hand.

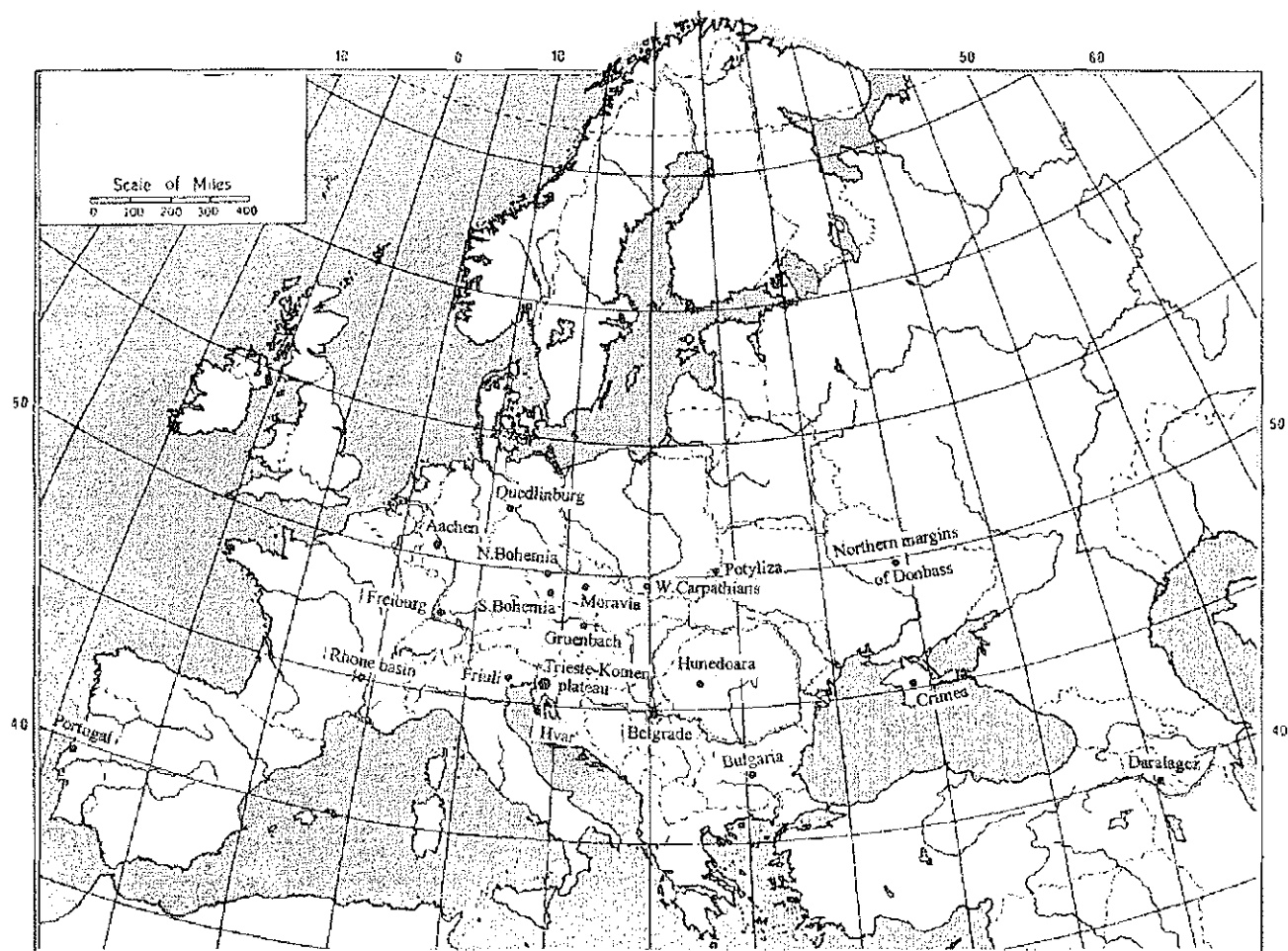
In Northern Italy, rich conifer flora is known from the Lower Jurassic of Grey Limestone of Veneto - Vecentino and Veronese - not far from just mentioned region (Wesley, 1956, 1958).

Conifers (chiefly, genus *Voltzia*) predominated in many Triassic floras of Central Europe (Dobruskina, 1993, 1994): Carnian Alps (Raibl), Karavanke in Slovenia, Northern Limestone Alps in Austrian Tyrol, the German Basin (for example, in *Voltzia* sandstone). As already said, a revision of the genus *Voltzia* would be needed for comparison and determination of our conifers.

### CONCLUSION

The first - preliminary and very short - review of the Slovenian Upper Cretaceous plants shows that in the Late Cretaceous very specific flora existed in the centre of Europe. When we speak about specificity of the flora we have in mind its composition - relations between different systematic groups in it, as well as systematic position of each plant.

According to its composition, the flora differs very much from the adjacent coeval floras and bears more resemblance to the Jurassic and Triassic floras of the re



**Fig. 5: Localities of the Upper Cretaceous plants in Europe and in the Transcaucasus.**  
**Sl. 5: Nahajališča zgornjekrednih rastlin v Evropi in Zakavkazju.**

gion. Sure, future investigations will discover more exact systematic relations of Slovenian plants. It is especially interesting for conifers. Conifers, from one hand, constitute the majority of studied plant assemblages. On another hand, they hint at the connection with old vegetation. Nevertheless, it is obvious that they differ enough from the Cretaceous plants known in Europe, North Africa and the Near East. And this conclusion does not depend on their belonging to one or another systematic group.

#### ACKNOWLEDGEMENTS

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We are indebted to the residents of Kazlje, Dobravlje, Križ and Tomaj that enabled our fieldwork on their land. We acknowledge our thanks to the curators Mrs. Katarina Krivic (Natural History Museum of Slovenia) and Dr. Ruggero Calligaris (Museo Civico di Storia Naturale di Trieste) for their assistance in the study of the specimens from both museal collections.



## ZGORNJEKREDNA FLORA SLOVENIJE

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## POVZETEK

O najdbah rastlinskih fosilov v ploščastih in laminiranih zgornjekrednih apnencih Tržaško-komenske planote je bilo doslej malo znanega. Kljub razmeroma številnim primerkom iz Komenskega apnenca, ki jih že desetletja hranita Prirodoslovni muzej Slovenije v Ljubljani in Museo Civico di Storia Naturale v Trstu, so rastlinski fosili v geološki literaturi ostali v senci številnih najdb fosilnih vretenčarjev, predvsem rib in reptilov, o katerih je pisal že Gorjanovič-Kramberger (1895). Iz santonijsko-campanijskega tomajskega apnenca rastlinski fosili niso bili znani. Informativno so bili omenjeni le v reviji *Annales*, v članku o najdbi skata rodu *Rhinobatos* (Jurkovšek & Kolar-Jurkovšek, 1995). Fosile maastrichtijskih rastlin Liburnijske formacije je deloma opisal Stache (1889).

Zgornjekredna fosilna flora Tržaško-komenske planote se od vseh poznanih zgornjekrednih rastlinskih združb razlikuje po prevladovanju iglavcev, medtem ko v drugih nahajališčih Evrope, Afrike in Bližnjega Vzhoda pripada bistveno večji delež kritosemenkam. V raziskani zgornjekredni fosilni flori se pojavljajo nekatere nove vrste in rodovi, ki v splošnem spominjajo na starejše tipe iglavcev.

Fosili so iz zbirke Prirodoslovnega muzeja Slovenije v Ljubljani, zbirke Museo Civico di Storia Naturale v Trstu in paleontološke zbirke Bogdana Jurkovška in Tee Kolar-Jurkovšek, ki je v skladu z veljavno zakonodajo registrirana pri Ministrstvu za kulturo Republike Slovenije in Prirodoslovnem muzeju Slovenije v Ljubljani.

**Okrajšave:**

PMS - Prirodoslovni muzej Slovenije / Natural History Museum of Slovenia, Ljubljana,

TS - Museo Civico di Storia Naturale di Trieste, Italija

Bf - Paleontološka zbirka Bogdana Jurkovška in Tee Kolar-Jurkovšek, Dol pri Ljubljani.

Kras lahko v ožjem tektonskem smislu opredelimo kot Tržaško-komensko planoto ali Komensko naravno grudo (Sl. 1), v širšem geotektonskem smislu pa Kras pripada obsežnim Zunanjim Dinaridom. Zanj so poleg plitvovodnih platformskih karbonatov značilni pojavi črnih ploščastih in laminiranih bituminoznih apnencev z rožencem, ki lokalno vsebujejo tudi fosile rastlin. Pojavljajo se znotraj različnih zgornjekrednih formacij od cenomanija do campanija. Na Formacijski geološki karti južnega dela Tržaško-komenske planote 1 : 50.000 (Jurkovšek et al., 1996) so te kamnine združene v členih tomajski in komenski apnenec. Starejši člen je komenski apnenec, ki pripada Povirski, Repenski in Sezanski formaciji, mlajši pa je santonijsko-campanijski tomajski apnenec Lipiške formacije (Sl. 2).

Zaradi splošne litološke podobnosti bituminoznih ploščastih in laminiranih apnencev z rožencem iz različnih formacij pri geološkem kartiranju severnega dela Tržaško-komenske planote danes upoštevamo predvsem tiste značilnosti, ki kažejo na različne načine in območja njihovega nastanka na karbonatni platformi.

Na osnovi raziskav sedimentacijskega okolja in mehanizmov nastanka recentnih z ogljikom bogatih morskih črnih skrilavcev sta Arthur in Sageman (1994) zaključila, da lahko te plasti nastajajo v petih večjih recentnih morskih okoljih:

1. globoki zaprti bazeni,
2. globoki bazeni ob robovih kontinentov,
3. kontinentalna pobočja, cona "upwellinga",
4. plitvi stratificirani bazeni,
5. priobalna medplimska okolja.

Šribar (1995) je menil, da so bila v primeru jugozahodne Slovenije zaradi položaja na karbonatni platformi za nastanek zgornjekrednih bituminoznih apnencev primerna le področja "upwellinga" in priobalni medplimski prostori.

Komenski apnenec iz okolice Komna so v novejšem času pogosto obravnavali med dokazi za drugi oceanski anoksični dogodek (OAE 2). Jenkyns (1991) je na osnovi primerjave razmer na Dinarsko-jadranski karbonatni platformi in razmer v širšem mediteranskem prostoru sklepal, da je med cenomanijem in turonijem obstajala razmeroma debela plast anoksične vode, ki je privedla v bazenu Umbria-Marche do nastanka plasti Bonarelli (Montanari et al., 1995). OAE 2 je sestavljalo več anoksičnih dogodkov, ki so poleg glavnega (plast Bonarelli)

povzročili nastanek še več tanjših z ogljikom bogatih plasti. Oceanski anoksični dogodki so vplivali na sedimentacijske razmere tudi na Dinarski karbonatni platformi jugozahodne Slovenije. Odločilni so bili predvsem za nastanek komenskega apnenca znotraj zgornjega dela cenomanijske Povirske formacije in cenomanijsko-turonijske Repenske formacije. Seveda so podobne anoksične razmere lahko nastale tudi v zaprtih lagunah, kjer je zaradi biološke produkcije in oksidacije prišlo do pomanjkanja kisika in nastanka z ogljikom bogatih plasti.

Še naprej ostaja deloma problematična natančna interpretacija nastanka tomajskega apnenca znotraj Lipiške formacije, saj je jasna povezava z evstatičnim dvigom morske gladine v tem delu Tetide nedorečena. Šribarju (1995) se zdi avtogeni nastanek anoksičnih razmer verjetnejši. O nekoliko globljem okolju nastanka teh plasti so na osnovi pojavljajočih se alodapičnih apnencev sklepali že Ogorelec in sodelavci (1987). V tomajskem apnencu, v nasprotju s komenskim, nismo nikjer zasledili znakov medplimskih razmer (Jurkovšek et al., 1996). Na dobro povezanost sedimentacijskega prostora z odprtim morjem kažejo pelagični mikro- in makrofosili, med katerimi prevladujejo amoniti. Summesberger in sodelavci (1996a, 1996b, 1999) so iz tomajskega apnenca opisali številne amonite z aptihi v bivalni kamrici in amonitne "roll marke", kar pomeni, da so v vodnem stolpcu nad dnom z anoksičnimi razmerami lahko živeli amoniti ter drugi nektonski in planktonski organizmi. V nekaterih nivojih je bilo ugotovljeno množično umiranje rib, ki ga povezuje s premešanjem dobro stratificirane vode v laguni. Močan vpliv pelagiala v tomajskem apnencu lahko na osnovi dosedanjih spoznanj povežemo tudi z rastjo morske gladine oziroma t.i. drugo pelagično epizodo v zgornjem santoniju in campaniju, ki je svoj maksimum dosegla v campaniju (Haq et al., 1987; Gusič & Jelaska, 1990; Kolar-Jurkovšek et al., 1996). Bogata fosilna makroflora, ki je opazna v vseh raziskanih lokalitetah tomajskega apnenca, izvira iz kopna, ki je verjetno že v zgornjem santoniju pričelo nastajati južno od tomajske lagune (Pleničar & Jurkovšek, 1997a, 1997b).

Organsko-kemični parametri komenskega in tomajskega apnenca so podobni, vendar je srednja vrednost organske materije ( $C_{org}=0,48\%$ ) v tomajskem apnencu v splošnem višja kot v komenskem apnencu, kar tomajski apnenec že uvršča na spodnjo mejo naftne potencialnosti (Ogorelec et al., 1996). V primerjavi s komenskim apnencem vsebujejo vzorci tomajskega apnenca več organske snovi vodnega porekla (alginita), medtem ko v komenskem apnencu prevladuje organska snov terestričnega izvora (ligninsko-huminski tip).

Raziskane muzejske vzorce zgornjekredne fosilne flore, ki jih hranita Prirodoslovni muzej Slovenije v Ljubljani in Museo Civico di Storia Naturale v Trstu, smo na osnovi evidenčnih listov razvrstili v več horizontov komenskega apnenca in v tomajski apnenec (Sl. 2). Primerki iz Volčjega Gradu so bili najdeni v komenskem apnencu Povirske formacije in so srednje do zgornjecenomanijske starosti. Rastlinski fosili, najdeni v Pliskovici in Krajni vasi, izvirajo iz komenskega apnenca santonijskega dela Sežanske formacije. Vse primerke, vključno z vzorci iz zbirke BJ, ki so bili zbrani na prostoru Kazelj, Dobravelj, Šepulj in Križa, uvrščamo v zgornjesantonijski do campanijski tomajski apnenec Lipiške formacije. Vzorec iz gradbišča avtoceste med Divačo in Sežano je bil odvzet v maastrichtijskem delu Liburnijske formacije, neposredno nad tanko premoško plastjo.

**Ključne besede:** flora, zgornja kreda, Dinarska karbonatna plošča, Tržaško-komenska planota, Slovenija

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## PLATE 1 - TABLA 1

Phlebopteris sp.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Figs. - Sl. 1a, 1b, 1c: PMS 301, x1, x2, x2, Šepulje

Equisetites sp.

Figs. - Sl. 2a, 2b: PMS 312, x1, x2, Kazlje

## PLATE 2 - TABLA 2

Brachyphyllum sp. nov.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Fig. - Sl. 1: BJ 1753, x1, Križ

Fig. - Sl. 2: BJ 1968, x1, Križ

Fig. - Sl. 3: BJ 1384, x1, Dobravlje

Fig. - Sl. 4: BJ 1735, x2, Križ

Fig. - Sl. 5: BJ 1967, x1, Križ

Fig. - Sl. 6: PMS 339, x1, Kazlje-Dobravlje

## PLATE 3 - TABLA 3

Brachyphyllum sp. nov.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Fig. - Sl. 1: PMS 328, x1, Avber

Fig. - Sl. 2: BJ 1734, x1, Kazlje

Fig. - Sl. 3: PMS 324, x1, Avber

Fig. - Sl. 4: PMS 293, x2, Dobravlje

Fig. - Sl. 5: BJ 1967, x2, Križ, (counterpart of the specimen on Pl. 2, fig. 5 - nasprotni odtis primerka na tab. 2, sl. 5)

## PLATE 4 - TABLA 4

Pagiophyllum sp. nov.

Fig. 1: BJ 1654, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 1: BJ 1654, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 2a, 2b: BJ 1558, x1, x2, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 2a, 2b: BJ 1558, x1, x2, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 3a, 3b: BJ 1746, x1, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 3a, 3b: BJ 1746, x1, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 4a, 4b: BJ 1471, x1, x1, Divača-Sežana; Liburnian Formation, Maastrichtian

Sl. 4a, 4b: BJ 1471, x1, x1, Divača-Sežana; Liburnijska formacija, maastrichtij

Figs. 5a, 5b: BJ 1538, x1, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 5a, 5b: BJ 1538, x1, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 6a, 6b: BJ 1848, x1, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 6a, 6b: BJ 1848, x1, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

## PLATE 5 - TABLA 5

Pagiophyllum sp. nov.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Fig. - Sl. 1: BJ 1658, x1, Dobravlje

Fig. - Sl. 2: PMS 336, x1, Kazlje-Dobravlje

Fig. - Sl. 3: BJ 1382, x1, Dobravlje

## PLATE 6 - TABLA 6

Pagiophyllum sp. nov.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Fig. - Sl. 1: BJ 1522, x1, Dobravlje

Figs. - Sl. 2a, 2b: BJ 1541, x1, x1, Kazlje

## PLATE 7 - TABLA 7

Conifer gen. nov.

Komen Limestone, Cenomanian

komenski apnenec, cenomanij

Figs. - Sl. 1a, 1b, 1c: TS 7786, x0.4, x1, x1, Volčji grad

## PLATE 8 - TABLA 8

Conifer gen. nov.

Komen Limestone, Cenomanian

komenski apnenec, cenomanij

Figs. - Sl. 1a, 1b, 1c: TS 7790, x0.4, x0.4, x1.3, Volčji grad

## PLATE 9 - TABLA 9

Conifer gen. nov.

Tomaj Limestone, U. Santonian-L. Campanian

tomajski apnenec, zgornji santonij-spodnji campanij

Figs. - Sl. 1a, 1b, 1c: BJ 1971, x0.4, x1, x0.7, Križ

## PLATE 10 - TABLA 10

Conifer gen. nov.

Komen Limestone, Cenomanian

komenski apnenec, cenomanij

Fig. - Sl. 1: TS 7785, x0.4; Fig. - Sl. 2: TS 7786, x0.35;

Fig. - Sl. 3: BJ 1547, x1, Volčji grad

## PLATE 11 - TABLA 11

Figs. - Sl. 1-6: Araucarites ? sp.

Figs. 1a, 1b: BJ 1559a, x1, BJ 1559b, x1, Kazlje; Tomaj

Limestone, U. Santonian-L. Campanian

Sl. 1a, 1b: BJ 1559a, x1, BJ 1559b, x1, Kazlje; tomajski

apnenec, zgornji santonij-spodnji campanij

Fig. 2: PMS 302, x1, Kazlje-Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 2: PMS 302, x1, Kazlje-Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 3: BJ 1516, x1, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 3: BJ 1516, x1, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 4: BJ 1513, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 4: BJ 1513, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 5: BJ 1745, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 5: BJ 1745, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 6: BJ 1548, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 6: BJ 1548, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 7: Conifer cone, BJ 1258, x1, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 7: Storž iglavca, BJ 1258, x1, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 8a, 8b, 9: Conifer scales, BJ 1561, x1, its counterpart, x1; BJ 1987, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 8a, 8b, 9: Luske iglavca, BJ 1561, x1, nasprotni odtis, x1; BJ 1987, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 10a, 10b: Conifer cone, BJ 1383, part and counterpart - x1, x2, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 10a, 10b: Storž iglavca, BJ 1383, nasprotna odtisa - x1, x2, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

PLATE 12 - TABLA 12

Figs. 1, 2, 3: *Magnoliaephyllum* sp., BJ 1562, part and counterpart, x1; BJ 1563, x1; BJ 1847, x1; Kazlje, Tomaj Limestone, U. Santonian-L. Campanian

Sl. 1, 2, 3: *Magnoliaephyllum* sp., BJ 1562, nasprotna odtisa, x1; BJ 1563, x1; BJ 1847, x1; Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij

Figs. 4-8: *Eucalyptus* sp., BJ 1744, x1, BJ 1988, x1, Križ; BJ 1986, x3, BJ 1986, x3, Kazlje; BJ 1863, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian

Sl. 4-8: *Eucalyptus* sp., BJ 1744, x1, BJ 1988, x1, Križ; BJ 1986, x3, BJ 1986, x3, Kazlje; BJ 1863, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 9: *Eucalyptus* ? sp., BJ 1701, x1, Kazlje, Tomaj Limestone, U. Santonian-L. Campanian

Sl. 9: *Eucalyptus* ? sp., BJ 1701, x1, Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 10: *Sassafras* sp., BJ 1560, x1, Kazlje, Tomaj Limestone, U. Santonian-L. Campanian

Sl. 10: *Sassafras* sp., BJ 1560, x1, Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 11: Fructification # 2, PMS 320, x1, Krajna vas, Komen Limestone, Santonian

Sl. 11: Fructification # 2, PMS 320, x1, Krajna vas, komenski apnenec, santonij

Fig. 12: Fructification # 1, BJ 1527, x1, Dobravlje, Tomaj Limestone, U. Santonian-L. Campanian

Sl. 12: Fructification # 1, BJ 1527, x1, Dobravlje, tomajski apnenec, zgornji santonij-spodnji campanij

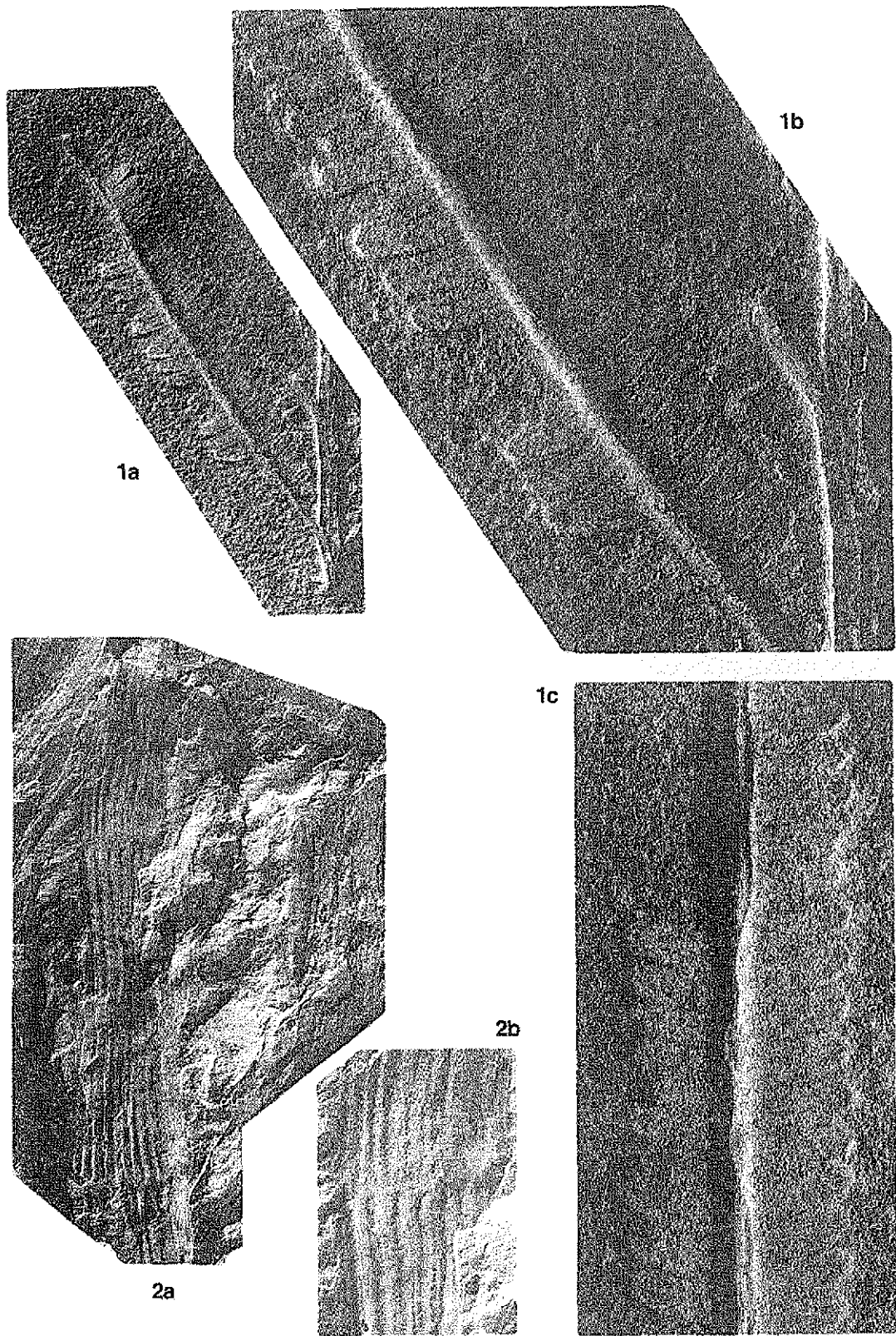


PLATE 1 - TABLA 1





PLATE 2 - TABLA 2





PLATE 3 - TABLA 3

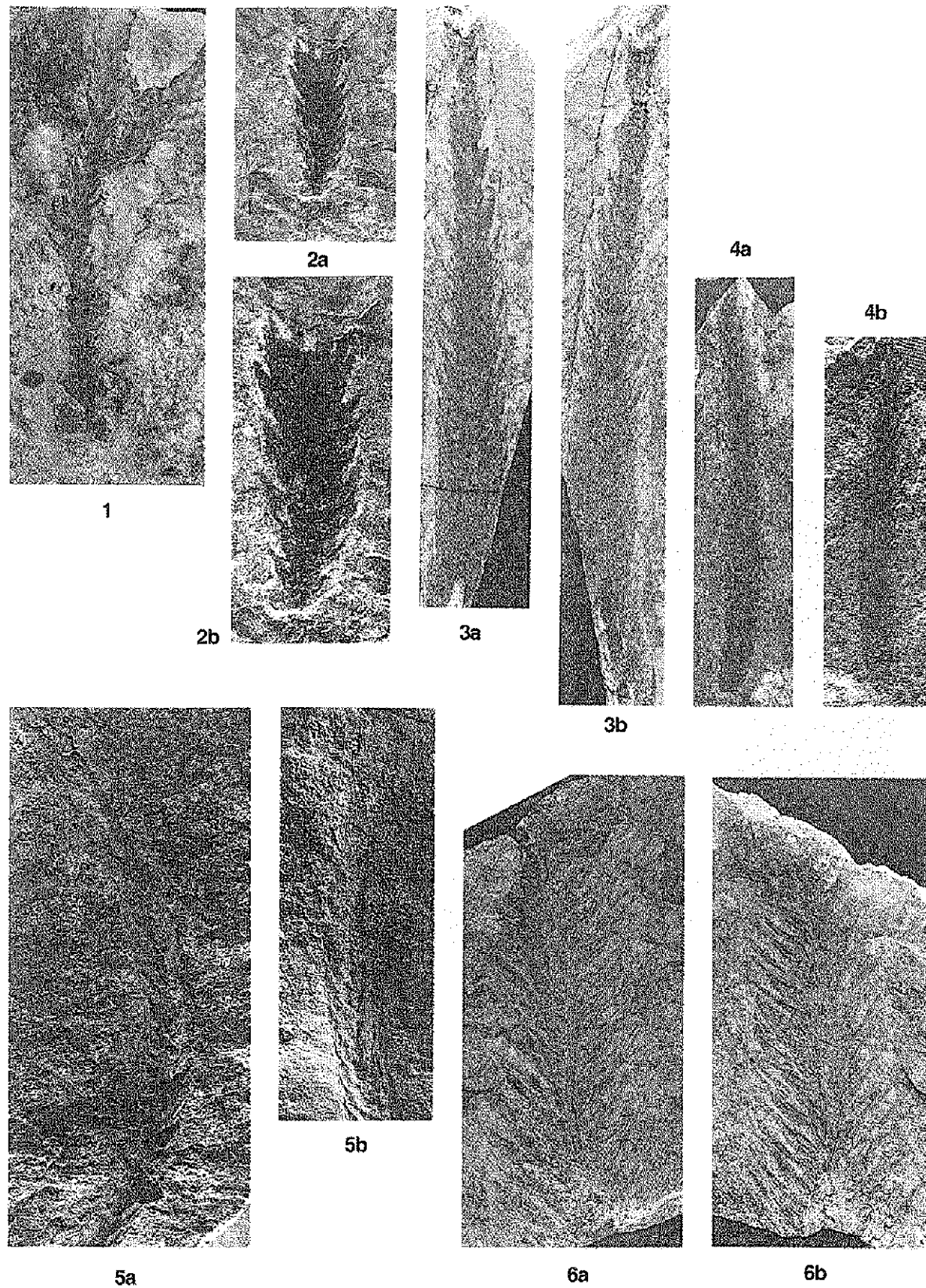


PLATE 4 - TABLA 4

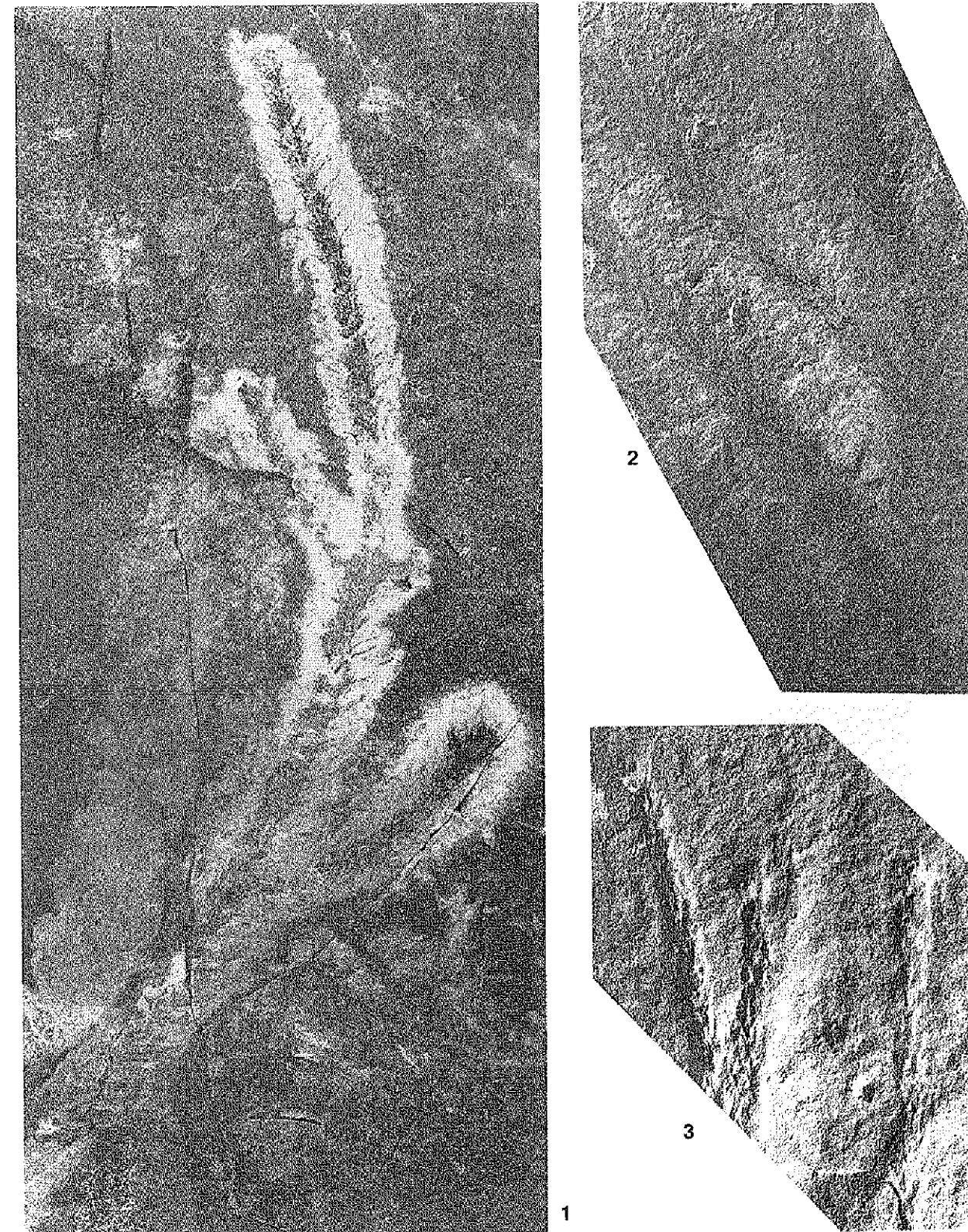


PLATE 5 - TABLA 5





1



2a



2b



PLATE 7 - TABLA 7

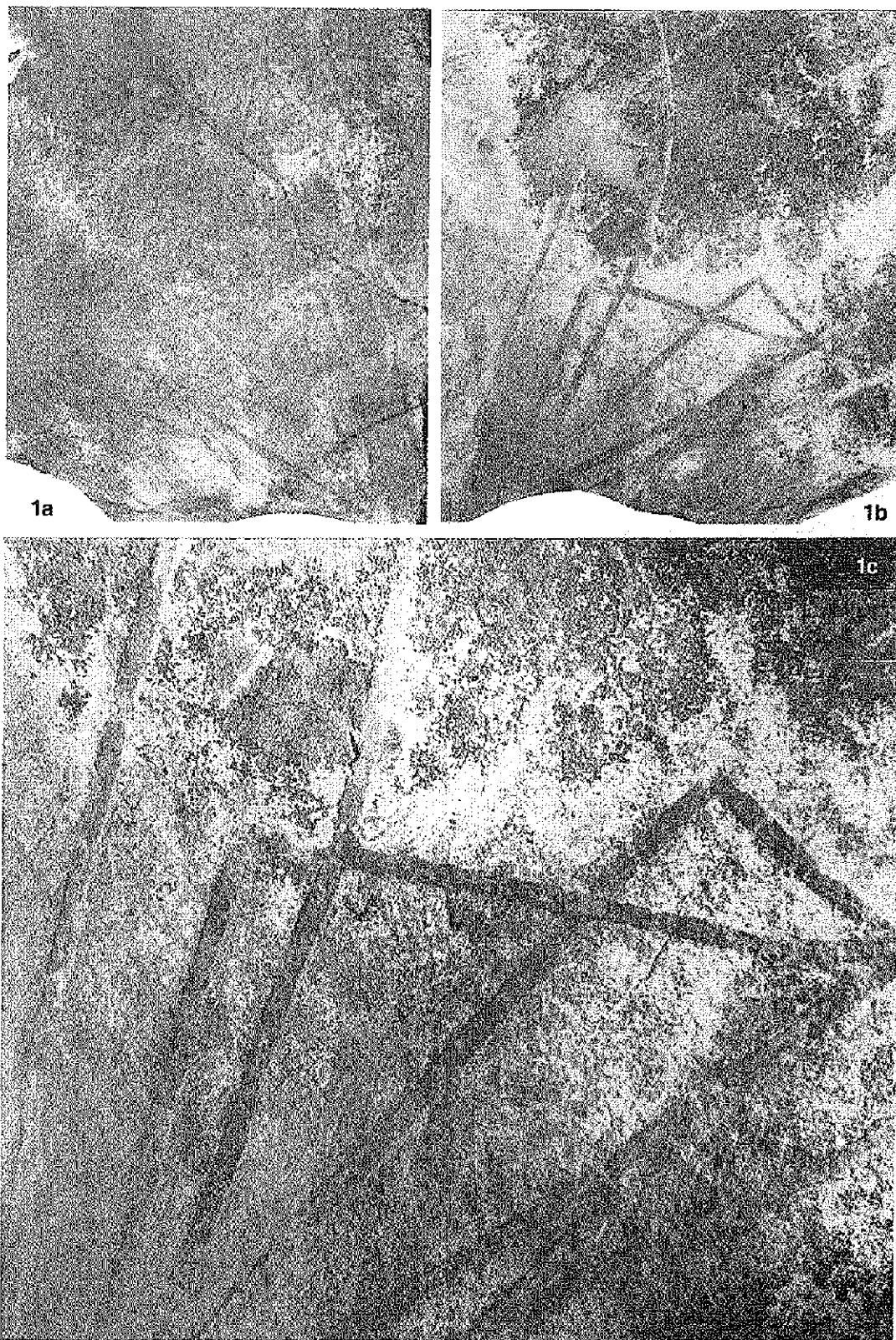


PLATE 8 - TABLA 8





PLATE 9 - TABLA 9

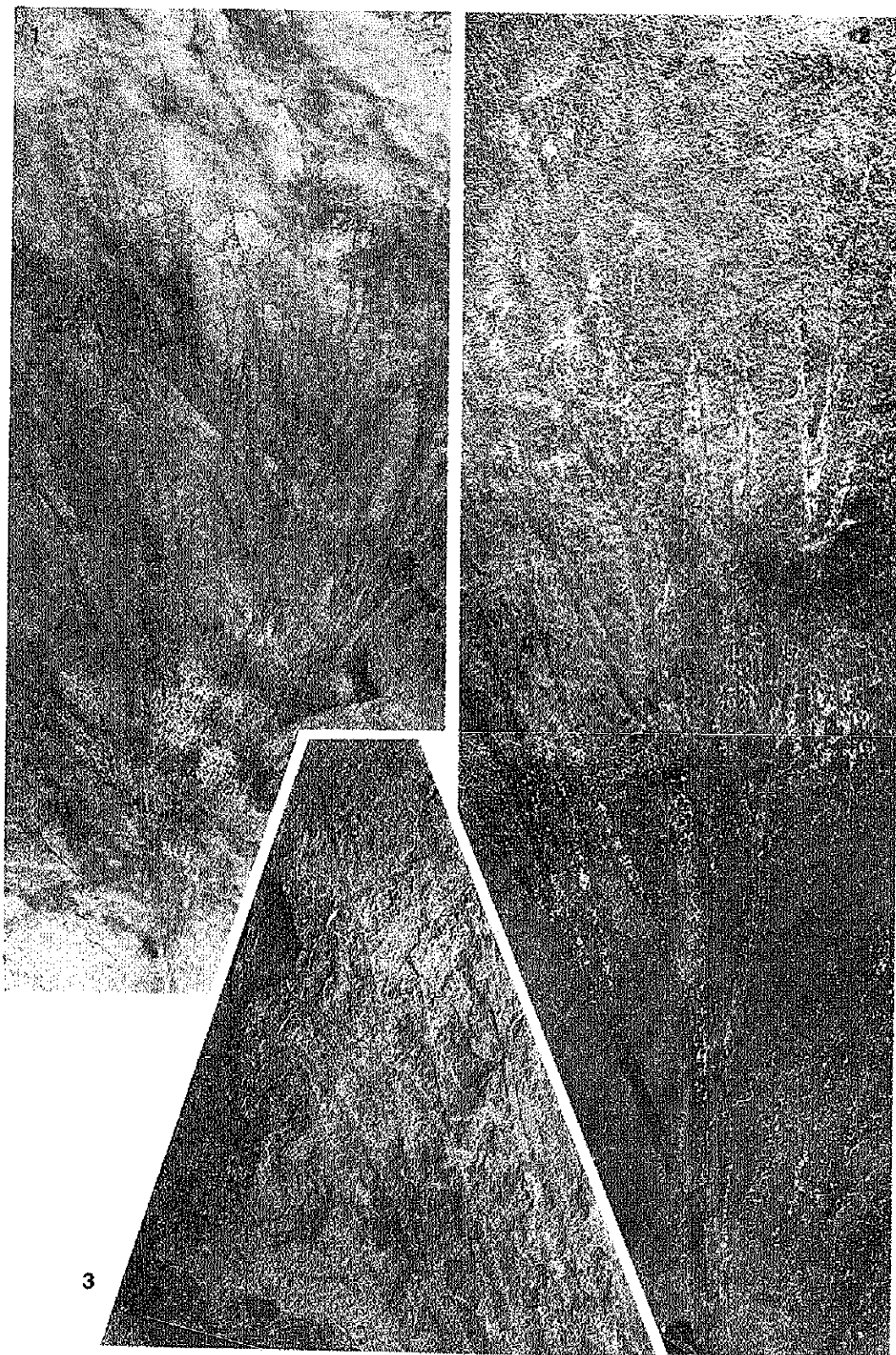


PLATE 10 - TABLA 10



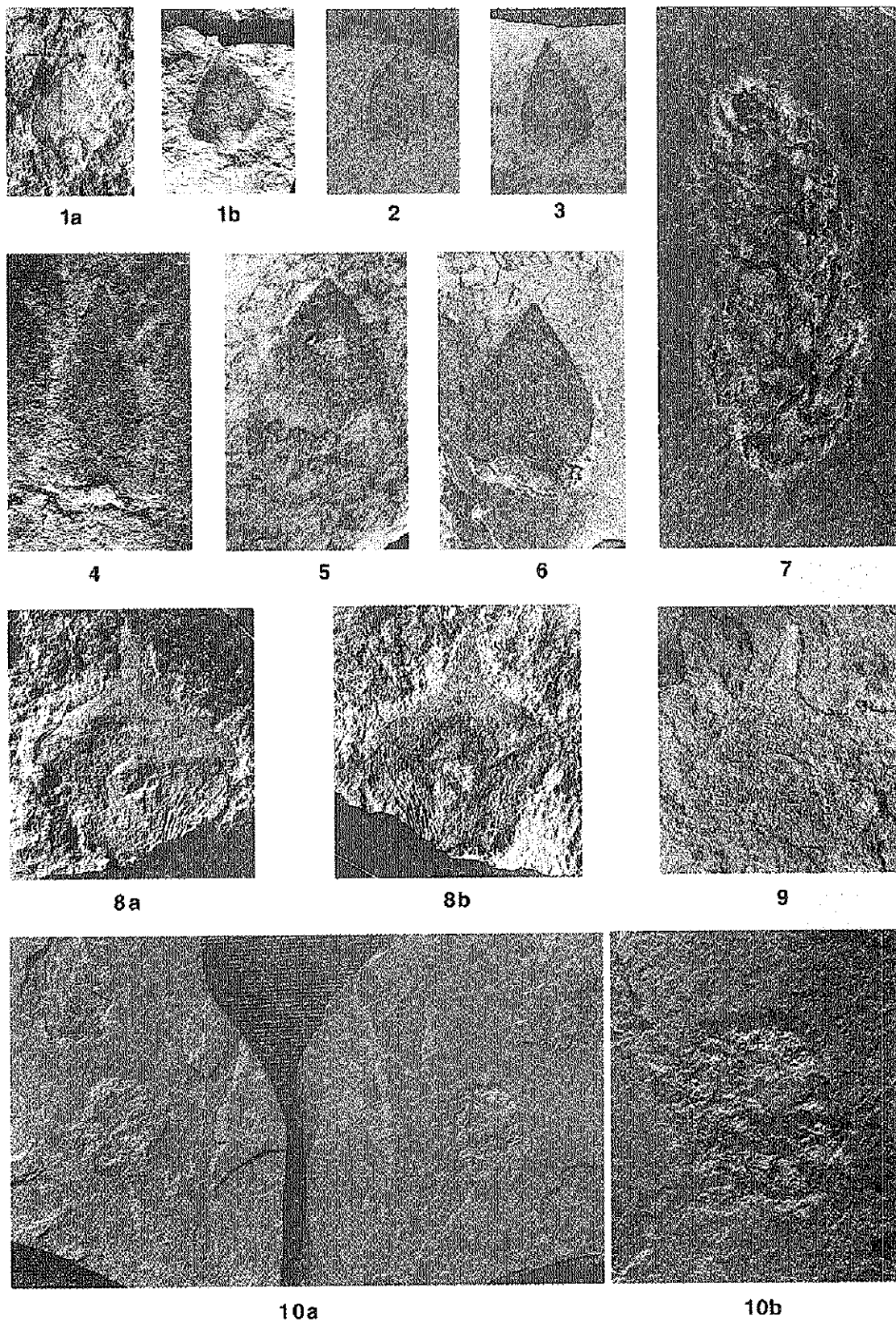
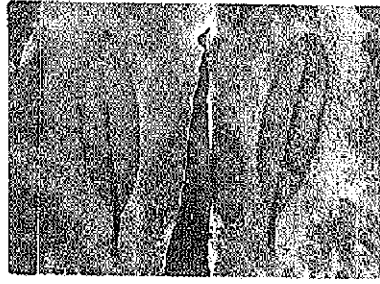


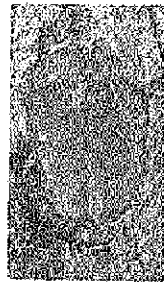
PLATE 11 - TABLA 11



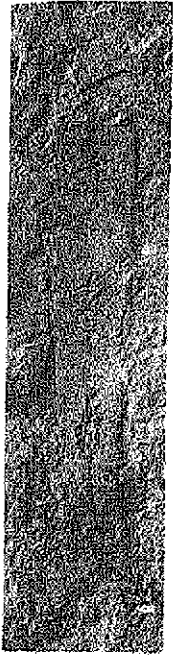
1



2



3



4



5



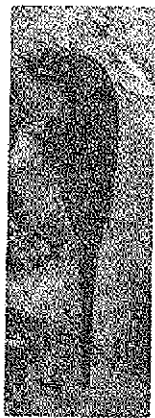
6



7



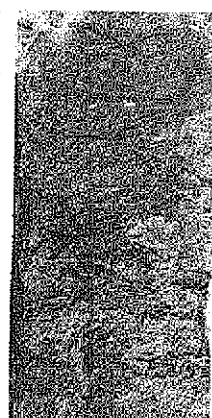
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9



10



11



12

PLATE 12 - TABLA 12

## NUMULITINE IZ OKOLICE VIPOLŽ V GORIŠKIH BRDIH

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## IZVLEČEK

Pri Vipolžah v Goriških Brdih je bilo doslej znano bogato najdišče numulitin, pred kratkim pa je bilo v bližini odkrito še drugo. Plasti z numulitinami so na obeh najdiščih iz najmlajšega cuisija ali iz prehoda cuisij - lutecij. Analiza favne kaže, da gre za dva s fosili bogata horizonta.

**Ključne besede:** foraminifere, fliš, eocen, Slovenija

## UVOD

## Flišne plasti v Goriških Brdih

Večji del Goriških Brd sestavljajo paleocenske in spodnjeeocenske flišne in flišu podobne kamnine, ki jih delijo na litološko različna člena. V severnem delu so kožbanske plasti, ki so v veliki meri nastajale iz podmorskih plazov, v južnem pa medanske plasti z značilnostmi turbiditnega fliša. Kožbanske plasti so se usedale v času močnejših orogenetskih premikanj, ko so v morje prihajale večje količine grobozrnatega materiala in so starejše od medanskih plasti (Pavlovec, 1966, 1980). V srednjem delu spodnjega eocena je prišlo do transgresije, v srednjem eocenu pa se je morje umaknilo s tega ozemlja (Buser, 1973). O načinu sedimentacije flišnih plasti v Goriških Brdih in sosednjem ozemlju so pisali največ italijanski geologi (Pirini Radrizzani *et al.*, 1986; Sartorio *et al.*, 1997; Tentor *et al.*, 1994; Tunis & Venturini, 1985).

V okolici Vipolž je že nekaj časa znano bogato najdišče numulitin (Cimerman *et al.*, 1974). Označujemo ga kot **Vipolže 1** in leži ob Mezeretovi domačiji s hišno številko 31, kakih 500 m severovzhodno od gradu. Največ numulitin je v breči in flišnem laporju na pobočju nad dolino Berše. Zaradi del v vinogradih je to najdišče precej uničeno. Poleg numulitin so tu diskocikline in redke alveoline, polžev in školjk je malo. Med numulitinami v flišu pogosto prevladuje mikrosferična generacija (De Zanche *et al.*, 1967). Zakaj je v

nekaterih najdiščih več ene oblike, ni dovolj pojasnjeno. Nemkov (1960) meni, da je potekalo spolno razmnoževanje v posebno ugodnih pogojih, ob katerih je nastajala mikrosferična generacija.

V Vipolžah 1 so doslej ugotovili naslednje numulitine: *Assilina maior maior*, *Ass. reichelti*, *Ass. cuvillieri*, *Ass. medanica*, *Ass. suteri*, *Nummulites friulanus*, *N. campesinus*, *N. manfredi* in *N. quasilaevigatus*. En primerek asiline je izredno velik (Cimerman *et al.*, 1974, Tab. 13, Sl. 2), vsekakor večji od tipičnih *Assilina maior maior*. Zdi se, da je bliže spodnjelutecijski podvrsti *Assilina spira abrardi*. Po tem bi lahko sodili, da je najdišče Vipolže 1 iz prehoda cuisij - lutecij.

Neumorni iskalec fosilov Stanislav Bačar iz Ajdovščine je pri Vipolžah odkril še eno bogato najdišče numulitin, ki ga označujemo **Vipolže 2**. Za posredovanje podatkov in pomoč pri nabiranju fosilov se S. Bačarju najtopleje zahvaljujemo.

Najdišče Vipolže 2 leži jugovzhodno od gradu kakih 100 m proč od kmetije Čeponovih s hišno številko Vipolže 14A. S fosili najbogatejši peščeni laporji so pod zidanico na robu vinograda. Poleg numulitin je tu precej diskociklin, polžev, školjk in koral. To najdišče ni daleč od Vipolž 1. Zato se je zastavilo vprašanje, ali je favna v obeh najdiščih enako stara in ali se podaljšujejo iste plasti iz Vipolž 2 v Vipolže 1. Opaziti je bilo razlike v favni, saj v Vipolžah 1 ni bilo najdenih toliko mehkužcev in koral kot v Vipolžah 2. V obeh najdiščih so numulitine slabo ohranjene, kar je povzročalo precej težav pri prepariranju in determiniranju.

## BIOCENOZA IN PALEOEKOLOGIJA NUMULITIN

Razmere za optimalen razvoj alveolin, numulitov, asilin, diskociklin in drugih velikih foraminifer so se nekoliko razlikovale. To je lahko posledica kombinacij morskih globin, osvetljenosti, substrata, rastlinstva in še kaj (cf. Hottinger, 1982, 1984). Velik del alveolinsko-numulitnega apnenca je bil odložen na odprtem, dobro prezračevanem plitvem šelfu (Jurkovšek et al., 1996). V nekaterih apnencih so zelo številne alveoline, v drugih numuliti, drugod zopet asiline. V srednji Istri so v nekaterih delih apnenecv pogoste velike asiline, to so *Assilina monacensis* ter *Ass. maxima* in tam je malo numulitov. Omenjenih velikih asilin iz fliša sploh ne poznamo. V cuijskem in lutecijskem apnencu pri Črnem Kalu prevladujejo v starejših horizontih alveoline, više so numuliti in nato asiline, ki jih je ponekod v Istri in na Kvarnerskih otokih toliko, da so uvedli izraz asilinski apnenec (Aubouin & Neumann, 1960). Po tem sklepamo, da so živele blizu zunanjemu robu platforme velike asiline, nekoliko bolj proti notranjosti numuliti in še bolj oddaljene od roba alveoline. Diskocikline so se pojavile zlasti v nekoliko poglobljajočem se morju. Vsekakor so različni rodovi bentoških foraminifer potrebovali nekoliko specifično okolje (Pavlovec, 1981).

Poseben problem so numulitine v flišnih plasteh. Računati moramo s tem, da so numuliti živeli v čistih, normalno slanah in toplih vodah, kakršne so danes v tropskih ali ob ekvatorju, pogosto blizu koralnih grebenov (Nemkov, 1960, 1962). Kačarava (1973) misli, da so asiline potrebovale nekoliko globlje morje. Gotovo pa so bile posamezne vrste tudi navezane na določene vrste morske vegetacije (Hottinger, 1977). Takšnih razmer pa ni bilo v morskem bazenu, kjer je nastajal fliš. Zato je jasno, da so bile numulitine prenešene v flišno morje s karbonatne platforme. Vendar se pojavlja vprašanje, zakaj niso v apnencih posamezne vrste enako pogoste kot v flišu. Enih je več v flišu, drugih v apnencu. Pri Vipolžah sta npr. pogosti numulitini *Assilina maior* in *Numulites friulanus*, ki jih iz apnenecv ne poznamo veliko. To si razlagamo z različnimi deli karbonatne platforme, od koder so bile numulitine prenešene v flišno morje. Najlaže so jih tokovi, valovi ali plazovi pobrali z zunanjega roba platforme, včasih morda tudi iz drugih prostorov. Mogoče je odnašanje numulitin v flišno morje potekalo samo v določenih krajših obdobjih. Izdelani so bili tudi modeli takšne sedimentacije (Pavlovec, 1969, 1982, 1988). Nedvomno pa lahko rečemo, da so numulitine v flišu večinoma uporabne za stratigrafske podatke, nikakor pa ne za ugotavljanje paleoekoloških razmer (Pavlovec, 1976).

## OPISI NUMULITIN

Pri opisih so uporabljene naslednje oznake: Dm = premer hišice; W = število zavojev; Z1, Z2, Z3... =

število sept v prvem, drugem, tretjem ... zavoju

***Assilina maior maior* Heim**

(Tabla 1, Sl. 2 in 3)

1963 *Assilina maior* Schaub - Pavlovec, 474-475, Sl. 35.

1972 *Assilina maior* Heim - Blondeau, Tab. 38, Sl. 16.

1974 *Assilina maior* Heim - Cimerman et al., 56-57, Tab. 10, 11, 12, 13, Sl. 1.

1981 *Assilina maior* Heim - Schaub, 200-202, Tab. 75, Sl. 1-26, Tab. 76, Sl. 1-37, Tab. 77, Sl. 1-30.

## Oblika B

Ploščata in nekoliko valovita hišica ima dvignjen centralni del. Na njem so nežni trni. Zunanji rob je zaokrožen. Proti robu sledijo radialni grebeni s septalnim podaljškom. Pri nekaterih primerkih so vidni tudi debelejši grebeni, ki potekajo nad zavojnim robom. Debelina hišic je od 2,0 do 2,9 mm. Zavoji se v sredini počasi, proti robu pa hitreje dvigajo. Zavojni rob je precej močan, vendar je najdebelejši v zunanjih zavojih. Septa so ravna ali rahlo ukrivljena. Kamrice so bolj visoke kot dolge.

## Oblika A

Grobi trni so najgostejši na sredini hišice. Proti zunanjemu robu sledijo podaljškom sept.

Zavojni rob je pri notranjih zavojih bolj tanek, v zunanjih se odebeli. Kamrice so nagnjene, bolj visoke kot široke. Septa so rahlo ukrivljena, najbolj v zunanjih zavojih. Prvi zavoj se hitro dvigne, drugi nekoliko zniža, drugi zavoji počasi naraščajo ali pa vsi zavoji enakomerno naraščajo. Prva kamrica je velika in okrogla.

Tab. 1: *Assilina maior maior*, oblika A (form A), Vipolže 1.

| Dm  | W | Z1 | Z2 | Z3 | Z4 |
|-----|---|----|----|----|----|
| 5,4 | 5 |    | 14 | 23 | 24 |
| 5,0 | 4 | 10 | 15 | 21 | 23 |

*Assilina maior maior*, oblika B (form B), Vipolže 2.

| Dm   | W  | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 |
|------|----|----|----|----|----|----|----|----|-----|
| 13,4 | 11 | 12 | 16 | 19 | 21 | 24 | 24 | 26 | 31  |
| 14,5 | 11 | 15 | 17 | 20 | 20 | 26 | 30 | 28 | 30  |

*Assilina maior maior*, oblika A (form A), Vipolže 2.

| Dm  | W | Z1 | Z2 | Z3 | Z4 |
|-----|---|----|----|----|----|
| 6,8 | 4 | 11 | 18 | 22 | 28 |
| 5,5 | 4 | 10 | 20 | 22 |    |
| 7,2 | 4 | 13 | 20 | 26 | 28 |
| 5,5 | 4 | 13 | 20 | 29 |    |



Primerki iz Vipolž imajo večinoma manjši premer kot Schaubovi (1981), ki navaja podatke od 6 do 10 mm. Premer najmanjše hišice v Vipolžah je 4,1 mm. Megalosferične oblike je v Vipolžah manj kot oblike B.

*Assilina maior maior* je zelo razširjena. Našli so jo v Rožacu v Furlaniji in drugod v Italiji, v Dobrinju na Krku, v Avstriji, Franciji, Španiji, v francoskih in švicarskih Alpah, na Madžarskem, na Krimu pa tudi v Aziji (Schaub, 1981).

***Assilina maior punctulata* Schaub**

1981 *Assilina maior punctulata* n. ssp. - Schaub, 205, Tab. 97, Sl. 13-21.

**Oblika A**

Na sredini hišice je nekaj posamičnih trnov. Vzдолž sept potekajo radialni grebeni. Prvi trije zavoji počasi in enakomerno naraščajo. Zadnji zavoj je višji od drugih. Kamrice so bolj visoke kot dolge, septa so rahlo nagnjena in malo upognjena. Najden je bil samo en primer ek megalosferične generacije. Prvič so našli to podvrsto v zgornjecujsijskih plasteh v najdišču Noax v Furlaniji (Schaub, 1981).

**Tab. 2: *Assilina maior punctulata*, oblika A (form A).**

|                                | Dm  | W | Z1 | Z2 | Z3 | Z4 |
|--------------------------------|-----|---|----|----|----|----|
| Vipolže 1                      | 5,6 | 4 | 8  | 17 | 28 | 28 |
| Schaub, 1981<br>Tab. 17, Sl. c | 6,2 | 4 | 8  | 15 | 23 |    |

***Assilina medianica* Pavlovec**

(Tabla 1, Sl. 4 in 9)

1974 *Assilina medianica* n. sp. - Cimerman *et al.*, 60-64 (non oblika A), Tab. 15, Sl. 1-2.

1981 *Assilina medianica* Pavlovec - Schaub, 217-218, Tab. 97, Sl. 22-5.

**Oblika B**

Ploščata hišica je na sredini rahlo udrt ali ravna. Nežni trni so razporejeni po celotni površini, vendar so na sredini bolj gosti, proti robu redkejši in združeni v nežne radialne grebene, razporejene po septalnih podaljških. Zavoji enakomerno naraščajo do sredine, tam ostanejo pri nekaterih primerkih enako visoki ali se celo nekoliko znižajo, pri drugih se tudi zunanji višajo. Septa so nežna in rahlo usločena. Kamrice so v notranjih zavojih bolj visoke kot dolge, v zunanjih pa izometrične.

**Oblika A**

Trni so razporejeni po celotni površini hišice in so bolj nežni kot pri vrsti *Assilina suteri*, ki ima zlasti močne v sredini. Večinoma so posamični, redkeje se združujejo v kratke radialne grebene. Pri naših primerkih ima *Assilina medianica* več nežnih trnov med

radialnimi podaljški, kar je tudi eden izmed kriterijev za ločitev obeh vrst. Zavoji enakomerno naraščajo in imajo tanek zavojni rob. Septa so rahlo do malo upognjena. Kamrice so malo nagnjene in so bolj visoke kot dolge. V zadnjih zavojih so izometrične. Prva kamrica je skoraj okrogla in večja od druge.

Ta vrsta je bila najdena v zgornjecujsijskih plasteh v Vipolžah (Cimerman *et al.*, 1974) in v Franciji (Schaub, 1981).

**Tab. 3: *Assilina medianica*, oblika B (form B).**

|                                | Dm  | W  | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 |
|--------------------------------|-----|----|----|----|----|----|----|----|----|----|-----|
| Vipolže 1                      | 7,4 | 10 |    | 15 | 15 | 19 | 23 | 23 | 23 | 26 |     |
|                                | 9,6 | 11 |    | 11 | 15 | 21 | 23 | 20 |    |    |     |
| Schaub, 1981<br>Tab. 17, Sl. h | 9,8 | 13 | 11 | 12 | 15 | 20 | 24 | 26 | 30 | 33 | 34  |

***Assilina medianica*, oblika A (form A).**

|                                 | Dm  | W | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 |
|---------------------------------|-----|---|----|----|----|----|----|----|
| Vipolže 1                       | 4,8 | 6 | 10 | 13 | 23 | 23 | 24 |    |
| Schaub (1981)<br>Tab. 17, Sl. h | 6,4 | 7 | 8  | 14 | 22 | 24 | 26 | 30 |

***Assilina medianica*, oblika B (form B), Vipolže 2.**

| Dm  | W  | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 |
|-----|----|----|----|----|----|----|----|----|----|-----|
| 10  | 13 |    | 13 | 16 | 18 | 19 | 23 | 22 | 26 | 28  |
| 8,7 | 13 |    | 12 | 17 | 20 | 20 | 24 | 25 | 30 |     |

***Assilina cuvillieri* Schaub**

(Tabla 1, Sl. 5)

1974 *Assilina* sp. (n. sp. Peyrac, Schaub) - Cimerman *et al.*, 59-60, Tab. 14.

1981 *Assilina cuvillieri* nov. sp. - Schaub, 210-211, Tab. 88, Sl. 22-26, Tab. 89, Sl. 1-49, Tab. 90, Sl. 1-17.

**Oblika B**

Hišica je ploščata in nekoliko valovita. Na rahlo dvignjenem srednjem delu so gosti nežni trni, ki se proti robu združujejo v krajše radialne grebene. Na sredini je hišica rahlo udrt.

**Oblika A**

Na sredini hišice so gosti trni, ki se proti robu združujejo v radialne grebene. Trni so lahko na sredini bolj grobi, proti robu nekoliko nežnejši. Hišica je ploščata, ravna ali ima na sredini rahlo udrtino. Zavoji potekajo pravilno, počasi naraščajo ali so enako visoki. Prvi zavoj je lahko nekoliko višji od drugega. Zavojni rob je tanek. Kamrice so skoraj pokončne ali rahlo nagnjene. Septa so ravna, tanka ali rahlo ukrivljena.

Tab. 4: *Assilina cuvillieri*, oblika A (form A), Vipolže 1.

| Dm  | W | Z1 | Z2 | Z3 | Z4 | Z5 |
|-----|---|----|----|----|----|----|
| 4,9 | 6 | 11 | 19 | 26 | 24 | 27 |
| 5,4 | 6 | 8  | 16 | 21 | 26 | 28 |
| 4,1 | 6 | 10 | 19 | 24 | 27 | 28 |

Assilina cuvillieri, oblika A (form A), Vipolže 2.

| Dm  | W | Z1 | Z2 | Z3 | Z4 |
|-----|---|----|----|----|----|
| 6,5 | 7 | 13 | 20 | 24 | 28 |
| 5,5 | 6 |    | 19 | 23 | 33 |

Vrsto *Assilina cuvillieri* so našli tudi pri Dobrinju na Krku, v Campu v Španiji in v Franciji. Znana je iz konca cuisija in začetka lutecija (Schaub, 1981).

**Assilina suteri Schaub**

(Tabla 1, Sl. 1 in 7)

1974 *Assilina medanica* n. sp., oblika A - Cimerman *et al.*, 64, Tab. 15, Sl. 3-6.

1981 *Assilina suteri* n. sp. - Schaub, 216-217, Tab. 95, Sl. 34-53, Tab. 96, Sl. 1-9.

## Oblika B

Hišica je ploščata, zunanji rob je zaokrožen. Na sredini so gosti grobi trni. Tam je pri nekaterih primerkih rahla udrtina. Proti zunanjemu robu so trni nežnejši od onih v sredini, večkrat so prekinjeni in sledijo poteku sept. Zavoji enakomerno naraščajo ali se od šestega zavoja naprej nekoliko hitreje višajo. Zavojni rob je tanek. Kamrice so v notranjih zavojih bolj visoke kot dolge, v zunanjih pa izometrične ali bolj dolge kot visoke. Septa so zlasti pri zunanjih zavojih rahlo ukrivljena.

## Oblika A

Na sredini hišice so gosti grobi trni. Proti robu so na površini hišice radialni grebeni, ki sledijo poteku sept. Zavoji počasni in enakomerno naraščajo, nekateri potekajo malo nepravilno. Kamrice so v notranjih zavojih bolj visoke kot dolge ali izometrične. Septa so rahlo usločena.

*Assilina suteri* je v obeh najdiščih pri Vipolžah precej pogosta. Oblike A je predvsem veliko v Vipolžah 2. Ta vrsta je živela v zgornjem cuisiju in spodnjem luteciju. Našli so jo že v Vipolžah, na Krku, na Bavarskem, v Franciji in v Španiji (Schaub, 1981).

Tab. 5: *Assilina suteri*, oblika B (form B), Vipolže 1.

| Dm   | W  | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 |
|------|----|----|----|----|----|----|----|----|----|----|
| 10,2 | 12 | 13 | 15 | 19 | 25 | 25 | 31 |    |    |    |
| 8,7  | 11 | 13 | 17 | 19 | 20 | 23 | 24 | 25 | 31 | 34 |
| 8,1  | 12 | 12 | 14 | 20 | 22 | 24 | 31 | 30 | 32 | 43 |
| 7,3  | 8  |    | 13 | 21 | 27 | 26 | 35 |    |    |    |
| 5,2  | 9  | 12 | 14 | 18 | 23 | 27 | 31 |    |    |    |

Assilina suteri, oblika A (form A), Vipolže 1.

| Dm  | W | Z1 | Z2 | Z3 | Z4 |
|-----|---|----|----|----|----|
| 4,4 | 3 | 8  | 13 |    |    |
| 5   | 2 | 10 | 15 |    |    |
| 4   | 4 | 10 | 16 | 22 | 27 |

Assilina suteri, oblika B (form B), Vipolže 2.

| Dm  | W  | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 |
|-----|----|----|----|----|----|----|----|----|----|----|
| 7,2 |    |    | 16 | 17 | 19 | 19 | 24 | 27 |    |    |
| 6,9 |    |    | 16 | 17 | 15 | 21 | 21 | 26 | 27 | 24 |
| 7,4 | 10 |    |    | 16 | 17 | 20 | 24 | 25 |    |    |

Assilina suteri, oblika A (form A), Vipolže 2.

| Dm  | W | Z1 | Z2 | Z3 | Z4 |
|-----|---|----|----|----|----|
| 3,3 | 4 | 10 | 15 | 19 | 25 |
| 4   | 5 | 11 | 14 | 20 | 23 |
| 3,4 | 4 | 10 | 17 | 21 | 25 |

Na najdišču Vipolže 1 je nekaj primerkov oblike B s premeri hišic manjšimi od 8 mm. Po Schaubu (1981) je premer hišic te vrste med 8 in 15 mm. Površina manjših primerkov je lahko bolj nežna. Trni so gostejši na sredini hišice, ki ima rahlo udrtino. Zavoji so nizki, kamrice so bolj visoke kot dolge. Zavojni rob je debel, septa precej ravna. Zato bi te primerke lahko uvrstili med oblike, ki jih Schaub označuje kot *Assilina aff. suteri*. Vprašanje pa je, ali ne bi kazalo opisati novo podvrsto.

**Assilina reicheli Schaub**

1951 *Assilina reicheli* n. sp. - Schaub, 215-216, Tab. 9, Sl. 25-27.

1974 *Assilina reicheli* Schaub - Cimerman *et al.*, 55-66, Tab. 9.

1981 *Assilina reicheli* Schaub - Schaub, 215, Tab. 95, Sl. 28-33.

## Oblika B

V sredini hišice so grobi trni, ki so proti robu razporejeni po septalnih podaljskih. Zavoji naraščajo do tretjega zavoja počasni, nato hitreje. Kamrice so v prvem zavoju visoke, nato so izometrične. V zunanjih zavojih so lahko bolj visoke kot dolge, redko izometrične. Zavoji so v primerjavi z vrsto *Assilina reicheli* iz Vipolž (Cimerman *et al.*, 1974) nižji in bolj ustrezajo opisom z najdišč Campo v Španiji in profila Schlieren v Švici (Schaub, 1981).

Ta vrsta je bila najdena predvsem v srednjecuisijskih najdiščih, redkeje v zgornjecuisijskih (Schaub, 1981).



Tab. 6: *Assilina reicheli*, oblika B (form B).

|   | Dm  | W  | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 |
|---|-----|----|----|----|----|----|----|----|----|----|
| Vipolže 1                               | 5   | 8  |    | 16 | 15 | 18 | 18 | 19 | 27 | 25 |
| Schaub, 1981<br>Tab. 95, Sl. 33         | 3,9 | 9  |    |    | 14 | 16 | 20 | 24 |    |    |
| Cimerman et al.,<br>1974<br>Tab. 5/1875 | 9,6 | 10 | 12 | 15 | 18 | 21 | 21 | 24 | 28 | 34 |

***Assilina* aff. *praespira* Douvillé**

(Tabla 1, Sl. 6 in 8)

1926 *Assilina praespira* Douvillé - Doncieux, 54-55, Tab. 6, Sl. 4-7.

1964 "*Assilina*" aff. *praespira* Douvillé - Hottinger, 1020, Sl. 12, 13.

1981 *Assilina* aff. *praespira* - Pavlovec, 76

To obliko smo označili *Assilina* aff. *praespira* enako kot Hottinger (1964), ki jo je kasneje prištel vrsti *Operculina marinellii* (= *Assilina marinellii*; Hottinger, 1977). Podobno obliko navaja Pavlovec (1963), in sicer iz Črnega Kala. Prava *Assilina marinellii* je iz srednjega in spodnjega cuisija, *Ass. praespira* pa iz spodnjega lutcija (Hottinger, 1977). Najbrž bi kazalo opisati novo vrsto, vendar imamo za to premalo primerkov. Zdi se, da je to prehodna oblika med omenjenima vrstama, med katerima je tudi časovna razlika okrog štiri milijone let.

*Assilina* aff. *praespira* ima več zavojev kot *Ass. marinellii*. Po velikosti je med *Assilina marinellii* in *Ass. praespira*. Megalosferična oblika vrste *Assilina praespira* ima večjo začetno kamrico, zavoji so nekoliko nižji, kamrice pa daljše kot pri *Ass. marinellii*.

V Vipolžah je bilo najdenih nekaj primerkov mikrosferične generacije. Ker so hišice zelo tanke in jih je težko razpoloviti po ekvatorialnem prerezu, so bile meritve narejene le pri tistih, pri katerih je na površini viden potek sept in zavojev.

Tab. 7: Oblika B (form B).

|                                       | D   | W   | Z1 | Z2 |
|---------------------------------------|-----|-----|----|----|
| Vipolže 1                             |     |     |    |    |
| <i>Assilina</i> aff. <i>praespira</i> | 4,6 | 2,5 | 8  | 16 |
| Hottinger, 1977; Sl. 25A              |     |     |    |    |
| <i>Assilina praespira</i>             | 7,2 | 3   | 8  | 17 |
| Hottinger, 1977; Sl. 26A              |     |     |    |    |
| <i>Assilina marinellii</i>            | 3,7 | 2   | 8  | 15 |

***Nummulites campesinus* Schaub**

(Tabla 2, Sl. 7)

1966 *Nummulites campesinus* n. sp. - Schaub, 361, Sl. 3 k, l, m, n.

1972 *Nummulites campesinus* Schaub - Blondeau, 159, Tab. 32, Sl. 15-23.

1974 *Nummulites campesinus* Schaub - Cimerman et al., 66, Tab. 17 in 18.

1981 *Nummulites campesinus* Schaub - Schaub, 83-85, Tab. 7, Sl. 23-44, Tab. 8, Sl. 1-22, Tab. 9, Sl. 1-20.

1984 *Nummulites campesinus* Schaub - Serra-Kiel, 70, Tab. I, Sl. 8-9, 10-12, 13-17.

1991 *Nummulites campesinus* Schaub - Kleiber, 70.

**Oblika B**

Schaub (1981) navaja debeline hišic od 3 do 5 mm, pri nekaterih naših primerkih je včasih nekoliko tanjša, in sicer od 2,1 mm naprej. Na površini so grobi trni. Zunanji rob je lahko precej oster. Premer hišic je manjši od 10 mm. Zavoji počasi naraščajo. Zavojni rob je močan. V notranjih zavojih so kamrice bolj visoke kot dolge, v zunanjih so izometrične ali bolj dolge kot visoke. Kamrice so nagnjene. Septa so upognjena.

**Oblika A**

Schaub (1981) navaja debeline hišic od 2,5 do 3,0 mm, eden od naših primerkov je bil debel komaj 1,9 mm. Na površini so grobi trni. Začetna kamrica je velika. Kamrice so bolj visoke kot dolge in rahlo nagnjene. Zavojni rob je močan. Septa so rahlo upognjena.

Tab. 8: *Nummulites campesinus*, oblika B (form B), Vipolže 1.

| Dm  | W  | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 |
|-----|----|----|----|----|----|----|----|----|----|-----|
| 6,9 | 12 |    |    | 15 | 21 | 21 | 29 | 30 | 34 |     |
| 8,2 | 12 | 12 | 16 | 20 | 22 | 23 | 27 | 28 | 36 | 37  |
| 7,5 | 12 | 13 | 17 | 18 | 23 | 26 | 30 |    |    |     |
| 8,4 | 11 |    | 15 | 21 | 27 | 31 | 26 | 31 |    |     |
| 3,7 | 7  |    | 12 | 14 | 15 | 22 | 23 |    |    |     |
| 4   | 10 |    | 11 | 13 | 19 | 21 | 24 | 25 | 26 | 35  |

*Nummulites campesinus*, oblika B (form B), Vipolže 2.

| Dm  | W  | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 | Z11 |
|-----|----|----|----|----|----|----|----|----|-----|-----|
| 8,5 | 16 | 17 | 17 | 20 | 22 | 26 | 28 | 29 | 36  | 37  |
| 8,6 | 14 |    |    | 22 | 23 | 27 | 29 | 34 |     |     |

*Nummulites campesinus*, oblika A (form A), Vipolže 2.

| Dm  | W | Z1 | Z2 | Z3 | Z4 | Z5 |
|-----|---|----|----|----|----|----|
| 4,2 | 6 | 14 | 19 | 25 | 22 | 25 |
| 5   | 7 | 10 | 17 | 24 | 27 | 34 |

Vrsta *Nummulites campesinus* je srednje in zgornjecuisijska oblika, prvič opisana iz Campa v Španiji. Našli so jo tudi pri Dobrinju na Krku (Schaub, 1981).

**Nummulites friulanus Schaub**

(Tabla 2, Sl. 1, 3, 5, 6)

1962 *Nummulites friulanus* n. sp. - Schaub, 538-539

1963 *Nummulites friulanus* Schaub - Pavlovec, 465, 534, Sl. 26-28.

1974 *Nummulites friulanus* Schaub - Cimerman et al., 64-65, Tab. 16.

1981 *Nummulites friulanus* Schaub - Schaub, 102-103, Tab. 6, Sl. 7-34.

1988 *Nummulites friulanus* Schaub - Pavlovec, 143, Sl. 3.

1991 *Nummulites friulanus* Schaub - Kleiber, 72.

**Oblika B**

Debelina primerkov iz Vipolž je od 2,5 do 3,7 mm. Schaub (1981) navaja tudi večje debeline med 2,5 in 6,0 mm. Prejšnje meritve debeline primerkov iz Vipolž so med 3,5 in 4,0 mm, premer hišic pa je manjši od 10 mm (Cimerman et al., 1974). Pri naših primerkih je premer hišic med 5,0 in 8,6 mm, po Schaubu (1981) od 5,0 do 12 mm. Na površini hišic so trni, ki so pri nekaterih primerkih bolj grobi, pri drugih bolj nežni. Radialni grebeni so ob zunanjem robu, ki je precej oster. Zavoji so nizki in se počasi višajo. V zunanjih zavojih so enako visoki ali se rahlo znižajo. Zavojni rob je močan. Kamrice so nagnjene in v notranjih zavojih bolj visoke kot dolge, v zunanjih večinoma bolj dolge kot visoke. Septa so rahlo upognjena in nagnjena.

**Oblika A**

Hišica je debela in ima precej oster zunanji rob. Po celotni površini so razporejeni grobi trni. Prva kamrica je velika in okrogla. Zavojni rob je večinoma tanek, vendar se njegova debelina precej spreminja. Zavoji naraščajo enakomerno. V notranjih zavojih so kamrice bolj visoke kot dolge, v zunanjih so izometrične ali bolj dolge kot visoke. Tanka septa so upognjena, kamrice so nagnjene.

**Tab. 9: *Nummulites friulanus*, oblika B (form B), Vipolže 1.**

| Dm  | W  | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 |
|-----|----|----|----|----|----|----|----|----|-----|
| 8   | 15 | 15 | 16 | 19 | 23 | 27 | 29 |    |     |
| 6,8 | 14 | 13 | 15 | 16 | 17 | 23 | 24 | 25 | 27  |
| 5,9 | 12 | 11 | 14 | 18 | 23 | 26 | 33 | 30 | 36  |
| 7,3 | 14 | 15 | 14 | 17 | 19 | 25 | 29 | 30 | 35  |

***Nummulites friulanus*, oblika A (form A), Vipolže 1.**

| Dm  | W | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 |
|-----|---|----|----|----|----|----|----|
| 4,6 | 6 | 9  | 13 | 22 | 27 | 33 |    |
| 3,4 | 6 | 11 | 14 | 21 | 26 | 34 | 37 |
| 3   | 5 | 12 | 18 | 24 | 28 |    |    |
| 4   | 5 | 10 | 16 | 20 | 21 | 26 |    |

***Nummulites friulanus*, oblika B (form B), Vipolže 2.**

| Dm  | W  | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 | Z11 |
|-----|----|----|----|----|----|----|----|----|-----|-----|
| 6,7 | 15 | 16 | 14 | 17 | 19 | 22 | 21 | 23 | 26  | 29  |
| 7   | 15 | 15 | 18 | 21 | 23 | 23 | 25 | 27 | 28  | 33  |
| 6,1 | 14 | 15 | 16 | 17 | 21 | 25 | 29 | 33 | 33  |     |
| 5,4 | 14 | 16 | 19 | 22 | 23 | 27 | 28 | 25 | 37  |     |

***Nummulites friulanus*, oblika A (form A), Vipolže 2.**

| Dm  | W | Z1 | Z2 | Z3 | Z4 | Z5 |
|-----|---|----|----|----|----|----|
| 3,7 | 6 | 11 | 19 | 30 | 28 |    |
| 3,7 | 5 | 11 | 15 | 23 | 30 | 35 |
| 3,7 | 5 | 11 | 16 | 20 | 23 | 25 |
| 4,1 | 6 | 8  | 13 | 19 |    |    |

Vrsta *Nummulites friulanus* je pri Vipolžah zelo pogosta. Pavlovec (Cimerman et al., 1974) navaja, da je pogosta tudi v najdišču holotipa pri Rožacu (Abbazia di Rosazzo; Schaub, 1962). Dobili so jo še pri Dobrinju na Krku in pri Campu v Španiji, povsod v zgornjecuisijskih plasteh (Schaub, 1981).

***Nummulites* aff. *lehneri* sensu Schaub 1981**

(Tabla 2, Sl. 4)

1962 *Nummulites lehneri* n. sp. - Schaub, 530, Tab. 1, Sl. 1-4.

1981 *Nummulites* aff. *lehneri* Schaub - Schaub, 97, Tab. 11, Sl. 13-27.

**Oblika B**

Na površini hišice so močni srpasti grebeni, vendar ni takšnih izrazitih trnov, kakršne vidimo pri Schaubovih primerkih (1981, Tab. 11). Zavoji enakomerno naraščajo, zavojni rob je debel. Kamrice so nagnjene. V notranjih zavojih so bolj visoke kot dolge, v zunanjih so izometrične. Septa so nagnjena in rahlo upognjena.

**Tab. 10: Oblika B (form B).**

|                        | Dm   | W  | Z1 | Z2 | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 |
|------------------------|------|----|----|----|----|----|----|----|----|----|----|
| Vipolže 1              | 7,5  | 9  |    |    | 19 | 18 | 21 | 24 |    |    |    |
| <i>N. aff. lehneri</i> |      |    |    |    |    |    |    |    |    |    |    |
| Schaub, 1962; Sl. 1    | 12,0 | 14 |    |    | 18 | 19 | 25 | 25 | 30 | 32 | 33 |
| <i>N. lehneri</i>      |      |    |    |    |    |    |    |    |    |    |    |

*Nummulites* aff. *lehneri* je manjši, zavoji so nekoliko višji in enakomerno naraščajo, zavojni rob je debelejši kot pri *N. lehneri*. Zelo verjetno je to nova podvrsta ali celo vrsta, sorodna obliki *Nummulites lehneri*.

**Nummulites praelorioli Herb & Schaub**

1972 *Nummulites lorioli* de la Harpe - Blondeau, Tab. 25, Sl. 18-19.

1981 *Nummulites praelorioli* Herb & Schaub - Schaub, 110-111, Tab. 31, Sl. 10-15, 17, 20, 21, 24, 26 in 28-31.

**Oblika B**

Hišica je valovita in ima zaokrožen rob. Na površini so srpasti grebeni in močni trni. Najbolj pogosta velikost hišic je med 15,7 in 27,2 mm. Zavoji so nizki in enakomerno naraščajo. Zavojni rob je v notranjih zavojih tanek, pri zunanjih debelejši. Kamrice so bolj visoke kot dolge. Septa so tanka in proti zunanjemu robu bolj nagnjena.

Vrsto *Nummulites praelorioli* so našli v zgornje-cuisijskih in spodnjelutecijskih plasteh, med drugim pri Rožacu v Furlaniji in pri Dobrinju na Krku (Schaub, 1981).

**Nummulites quasilaevigatus Pavlovec**

(Tabla 2, Sl. 2)

1974 *Nummulites quasilaevigatus* n. sp. - Cimerman et al. 69, Tab. 22 in 23.

1981 *Nummulites quasilaevigatus* Pavlovec - Schaub, 171, Tab. 60, Sl. 11-17.

**Oblika B**

Površina hišice je prekrita je s srpastimi grebeni. Zavoji enakomerno naraščajo. Zavojni rob je tanek.

Kamrice so v notranjih zavojih bolj visoke kot dolge, v zunanjih bolj dolge kot visoke. Septa so v zunanjih zavojih tanka in bolj nagnjena kot v notranjih.

**Tab. 11: Nummulites quasilaevigatus, oblika B (form B).**

|                                     | Dm   | W  | Z3 | Z4 | Z5 | Z6 | Z7 | Z8 | Z9 | Z10 | Z11 | Z12 |
|-------------------------------------|------|----|----|----|----|----|----|----|----|-----|-----|-----|
| Vipolže 2                           | 11,0 | 15 | 15 | 21 | 25 | 27 | 33 | 32 | 31 | 33  | 37  | 33  |
| Cimerman et al., 1974 inv. št. 1848 | 10,5 | 11 |    | 24 |    | 32 | 36 | 36 | 44 | 52  |     |     |

V Vipolžah je vrsta *Nummulites quasilaevigatus* redka. Našli so jo še v Španiji, v Furlaniji, na Krku in v Iranu, povsod v zgornjecuisijskih plasteh (Schaub, 1981).

**ZAKLJUČEK**

V obeh najdiščih pri Vipolžah so zgornjecuisijske medanske plasti, morda celo iz prehoda cuisij - lutecij. Med fosilno favno so manjše razlike. V Vipolžah 1 so *Assilina maior punctulata*, *Ass. reicheli* in *Nummulites* aff. *lehneri*, ki jih v Vipolžah 2 ni, v Vipolžah 2 pa *Nummulites praelorioli* in *N. quasilaevigatus*, ki ju v Vipolžah 1 ni. V najdišču Vipolže 2 je tudi makrofavna, predvsem korale, školjke in polži, ki so v Vipolžah 1 zelo redki. Po tem sklepamo, da ti najdišči nista nadaljevanje istega flišnega horizonta, čeprav sta enake starosti.

**Tab. 12: Pogostost numulitin v Vipolžah.**

**Tab. 12: Abundance of nummulitins at Vipolže.**

|                              | oblika B (form B) |     |     |     | oblika A (form A) |   |     |     |
|------------------------------|-------------------|-----|-----|-----|-------------------|---|-----|-----|
|                              | ZR                | R   | S   | V   | ZR                | R | S   | V   |
| <i>Ass. maior maior</i>      |                   |     | o   | x   |                   | x |     | o   |
| <i>Ass. maior punctulata</i> |                   |     |     |     | x                 |   |     |     |
| <i>Ass. medanica</i>         |                   | x o |     |     |                   | x |     |     |
| <i>Ass. cuvillieri</i>       |                   | x   |     |     |                   | o | x   |     |
| <i>Ass. suteri</i>           |                   |     | x o |     |                   |   | x o |     |
| <i>Ass. reicheli</i>         | x                 |     |     |     |                   |   |     |     |
| <i>Ass. aff. praespira</i>   |                   | o   |     |     |                   | x |     |     |
| <i>N. campesinus</i>         |                   |     | o   | x   |                   |   | o   |     |
| <i>N. friularus</i>          |                   |     |     | x o |                   |   |     | x o |
| <i>N. aff. lehneri</i>       | x                 |     |     |     |                   |   |     |     |
| <i>N. praelorioli</i>        |                   |     |     | o   |                   |   |     |     |
| <i>N. quasilaevigatus</i>    |                   |     |     | o   |                   |   |     |     |

Ass. = *Assilina*; N. = *Nummulites*; ZR = zelo redko (very rare); R = redko (rare); S = srednjeveliko (medium abundant); V = pogosto (abundant); x = Vipolže 1; o = Vipolže 2

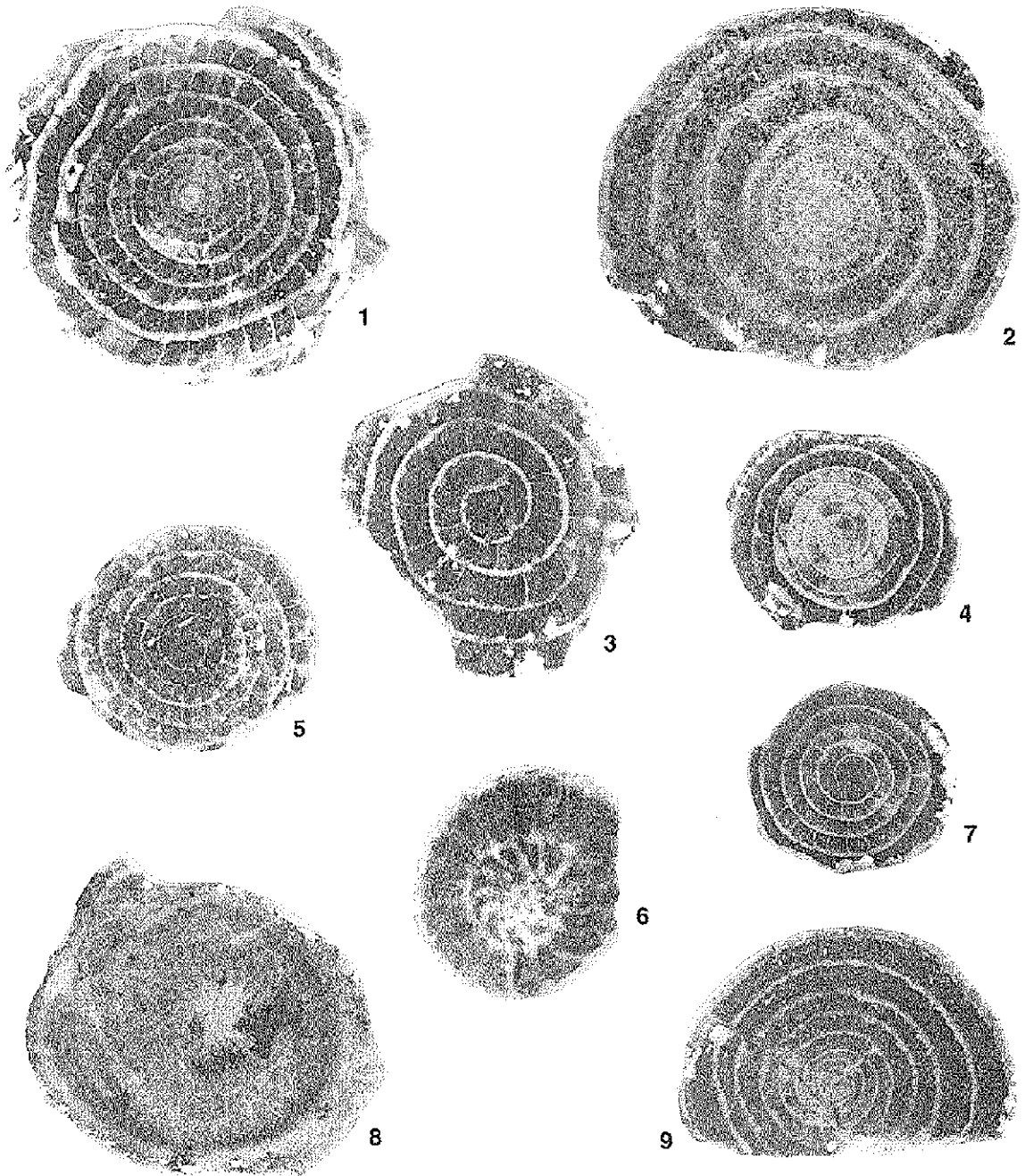


TABLA 1 - PLATE 1

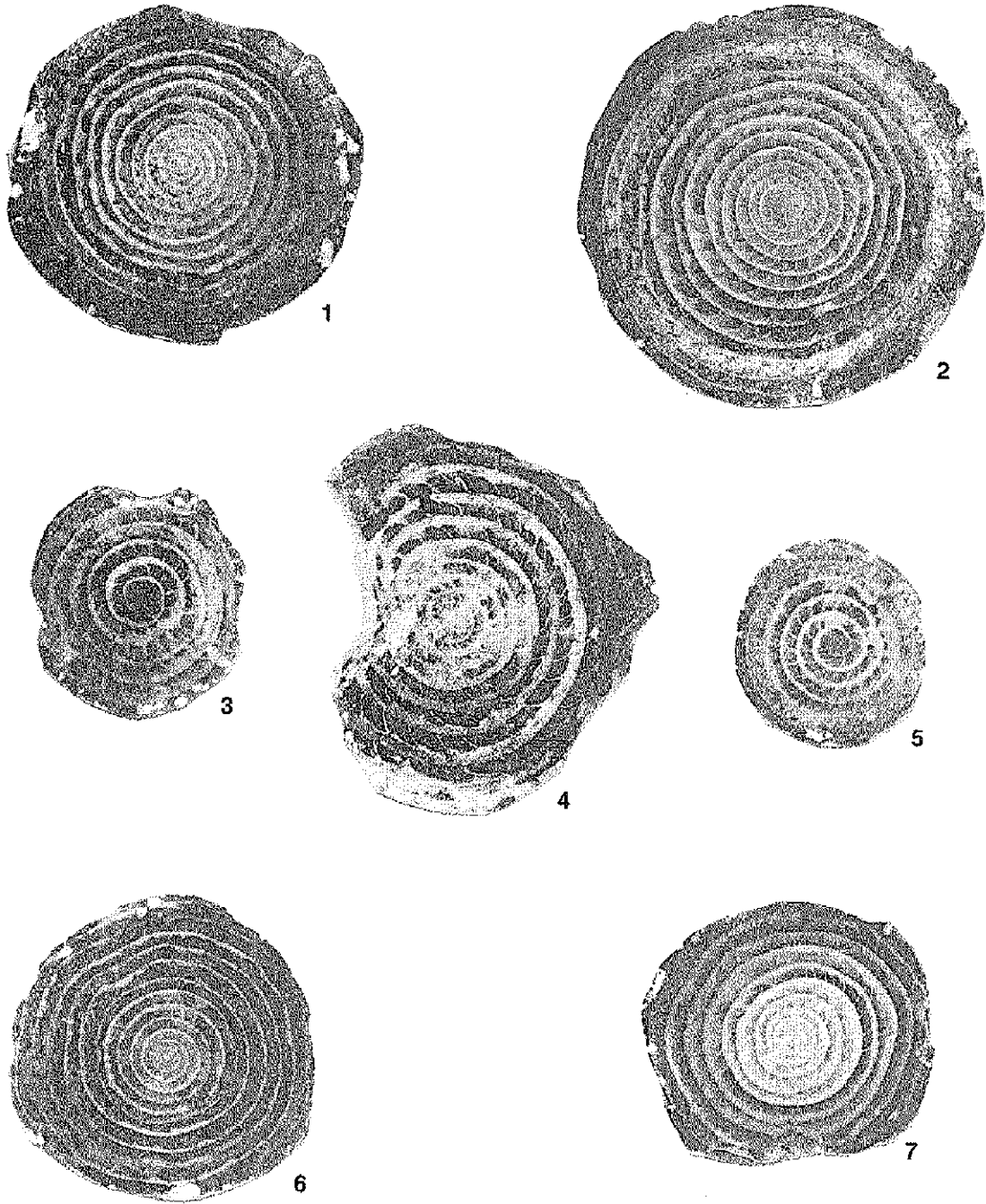


TABLA 2 - PLATE 2

TABLA 1 - PLATE 1

- Sl. 1: *Assilina suteri* Schaub, oblika B, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 1: *Assilina suteri* Schaub, B form, equatorial section, Vipolže 1, enlarged 7.5x.
- Sl. 2: *Assilina maior maior* Heim, oblika B, ekvatorialni prerez, Vipolže 2, 5 x pov.  
 Fig. 2: *Assilina maior maior* Heim, B form, equatorial section, Vipolže 2, enlarged 5x.
- Sl. 3: *Assilina maior maior* Heim, oblika A, ekvatorialni prerez, Vipolže 2, 7,5x pov.  
 Fig. 3: *Assilina maior maior* Heim, A form, equatorial section, Vipolže 2, enlarged 7.5x.
- Sl. 4: *Assilina medanica* Pavlovec, oblika A, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 4: *Assilina medanica* Pavlovec, A form, equatorial section, Vipolže 1, enlarged 7.5x.
- Sl. 5: *Assilina cuvillieri* Schaub, oblika A, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 5: *Assilina cuvillieri* Schaub, A form, equatorial section, Vipolže 1, enlarged 7,5x.
- Sl. 6: *Assilina aff. praespira* Douvillé, oblika A, površina hišice, Vipolže 1, 7,5x pov.  
 Fig. 6: *Assilina aff. praespira* Douvillé, A form, surface of the test, Vipolže 1, enlarged 7.5x.
- Sl. 7: *Assilina suteri* Schaub, oblika A, ekvatorialni prerez, Vipolže 2, 7,5x pov.  
 Fig. 7: *Assilina suteri* Schaub, A form, equatorial section, Vipolže 2, enlarged 7.5x.
- Sl. 8: *Assilina aff. praespira* Douvillé, oblika B, površina hišice, Vipolže 2, 5 pov.  
 Fig. 8: *Assilina aff. praespira* Douvillé, B form, surface of the test, Vipolže 2, enlarged 5.
- Sl. 9: *Assilina medanica* Pavlovec, oblika B, ekvatorialni prerez, Vipolže 1, 5x pov.  
 Fig. 9: *Assilina medanica* Pavlovec, B form, equatorial section, Vipolže 1, enlarged 5x.

TABLA 2 - PLATE 2

- Sl. 1: *Nummulites friulanus* Schaub, oblika B, ekvatorialni prerez, Vipolže 2, 7,5x pov.  
 Fig. 1: *Nummulites friulanus* Schaub, B form, equatorial section, Vipolže 2, enlarged 7.5x.
- Sl. 2: *Nummulites quasilaevigatus* Pavlovec, oblika B, ekvatorialni prerez, Vipolže 2, 5x pov.  
 Fig. 2: *Nummulites quasilaevigatus* Pavlovec, B form, equatorial section, Vipolže 2, enlarged 5x.
- Sl. 3: *Nummulites friulanus* Schaub, oblika A, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 3: *Nummulites friulanus* Schaub, A form, equatorial section, Vipolže 1, enlarged 7.5x.
- Sl. 4: *Nummulites aff. lehneri* Schaub, oblika B, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 4: *Nummulites aff. lehneri* Schaub, B form, equatorial section, Vipolže 1, enlarged 7.5x.
- Sl. 5: *Nummulites friulanus* Schaub, oblika A, ekvatorialni prerez, Vipolže 2, 7,5x pov.  
 Fig. 5: *Nummulites friulanus* Schaub, A form, equatorial section, Vipolže 2, enlarged 7.5x.
- Sl. 6: *Nummulites friulanus* Schaub, oblika B, ekvatorialni prerez, Vipolže 1, 7,5x pov.  
 Fig. 6: *Nummulites friulanus* Schaub, B form, equatorial section, Vipolže 1, enlarged 7.5x.
- Sl. 7: *Nummulites campesinus* Schaub, oblika B, ekvatorialni prerez, Vipolže 1, 5x pov.  
 Fig. 7: *Nummulites campesinus* Schaub, B form, equatorial section, Vipolže 1, enlarged 5x.

## THE NUMMULITINS FROM THE SURROUNDING OF VIPOLŽE IN GORIŠKA BRDA (WESTERN SLOVENIA)

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### SUMMARY

About 500 m northeast of Vipolže castle in Goriška Brda a rich locality of nummulitins Vipolže 1 that has been known for years is situated (Cimerman et al., 1974). Southeast of Vipolže castle, 100 meters from Vipolže 14A, a second locality - Vipolže 2 - has been discovered recently. At the first locality the new species *Assilina medanica*



and *Nummulites quasilaevigatus* were reported to occur with particularly abundant *Assilina maior maior* and *Nummulites friulanus*. *Schaub (1981)* attributed the megalospheric form of *Assilina medianica* to the species *Ass. suteri*. At Vipolže 2, *Assilina maior maior*, *Ass. medianica*, *Ass. cuvillieri*, *Ass. suteri*, and *Ass. aff. praespira* were found. The latter is most probably a new species or subspecies; however, too few specimens were found. *Nummulites campesinus*, *N. friulanus*, *N. praelorioli* and *N. quasilaevigatus* were also determined. In table 12 an overview of the established nummulitines is presented. In tables 1 to 11 numeric data for individual forms are tabulated, where *Dm* denotes the test diameter, *W* whorls number, *Z1*, *Z2*, *Z3*, ... number of the septa in the first, second, third... whorl.

At both Vipolže localities beds of Late Cuisian occur, perhaps even of the transition Cuisian-Lutetian, as indicated by several nummulitines that are close to Early Lutetian forms. The two localities differ in smaller features. The forms *Assilina maior punctulata*, *Ass. reicheli* and *Nummulite aff. lehneri* were not found at Vipolže 2 where, in contrast, the macrofauna, especially corals, bivalves and gastropods are more abundant. This leads to the conclusion that the localities are not exposures of the same flysch horizon. The differences of fauna seem to be the result of different ways of transport of organic material into the sea.

**Key words:** foraminifers, flysch, Eocene, Slovenia

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## A STUDY OF THE MORPHOLOGICAL VARIABILITY OF *RADIOLITES MARINII* CAFFAU & PLENIČAR (RADIOLITIDAE), LATE CENOMANIAN, KARST OF GORIZIA, ITALY

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### ABSTRACT

The species *Radiolites marinii* Caffau & Pleničar is very abundant in the rudist assemblages of the limestone sequence of the area of "Archi", in the southeastern part of the Karst of Gorizia, from the Upper Cenomanian age.

The good preservation-state of several specimens found separately in the dolonstone allowed to analyse and describe in detail the external morphology of the shell of this species. The main feature of the external morphology is the difference between the upper and the lower part of the shell.

Taking into account that this feature was observed in all adult specimens, transverse sections were made at the lower, middle (area where there is a change in the ornamentation) and upper part of the shell. Morphometrical values regarding the shell area (*Sa*), the inner area of the shell (*Ia*), the external perimeter (*Ep*) and the internal perimeter (*Ip*) of the shell were obtained from each transverse section by image analysis.

The analysis of these data indicated that the change in morphology could be due to a strong biological stress that markedly influenced the physiological trend of calcitic secretion for the building up of the shell in individuals of this species.

**Key words:** rudists, morphological variability, Late Cenomaniana, image analysis

### INTRODUCTION

Caffau and Pleničar (1991) described the rudist-rich assemblage of the limestone sequence of the locality of "Archi" in the southeastern part of the Karst of Gorizia. The study of the rudist fauna brought to light the new species *Radiolites marinii* n.sp. (*op. cit.*, pp. 268-269, Pl. 5, Figs. 1-4; Pl. 6, Figs. 1-3). Fossil material was found in dolonstones where specimens were very well preserved. The optimal preservation state of rudist shells allowed to describe in detail the external morphological characters of all rudist specimens found, in particular those of the species *R. marinii*.

The aims of this work are (i) to describe in detail the

variations of the external ornamentation of the shell of the lower valve of *R. marinii* (ii) to analyse whether there is a relationship between the morphological variability of the shell of this species and their life environment by morphometrical analysis (iii) to supply further stratigraphic and palaeoenvironmental information of this area of the carbonatic platform.

### Stratigraphic setting

Moschenizza is a hill characterised by light and grey fossiliferous limestones and dolonstones.

The sequence is divided in the following three units, from the most ancient to the most recent one:

1. Packstone/grainstone (7.5 m thick) with rare "bouquets" of *Praeradiolites fleuriaus* (d'Orbigny), singly specimens of *R. marinii* and *Radiolites radiosus* d'Orbigny.

In addition, abundant specimens of *Chondrodonta joannae* (Choffat) and *Neithea fleuriausiana* (d'Orbigny) are present.

2. Dolonstone (2.5 m thick) characterised by a rudist assemblage of many species, such as *Radiolites carsicus* Caffau & Pleničar, *Radiolites presauvagesi communis* Polsak, *R. radiosus* d'Orbigny, *Eoradiolites zucchi* Caffau & Pleničar, *Eoradiolites adriaticus* Caffau & Pleničar, *P. fleuriaus*, requieniids, *C. joanne* and *N. fleuriausiana*.

3. Floatstone with a matrix of silty bioclastic packstone (5 m thick) with scarce specimens of *R. carsicus*, *P. fleuriaus* and requieniids.

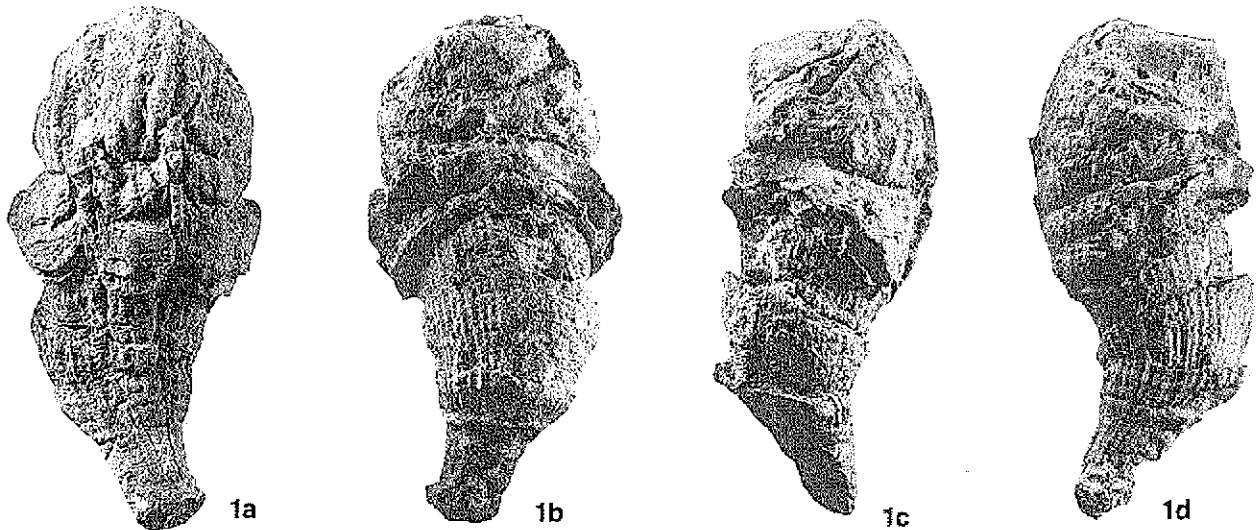
The bottom of this sequence (unit 1) represents the appearance of the first communities of *C. joannae* and

radiolitids that served as a rigid substratum for the subsequent generations of radiolitids and requieniids (unit 2). In this second unit there is the major faunistic diversification of rudists. In unit 3 the rudist fauna progressively diminishes and disappears at the top of the sequence.

The rudist species *P. fleuriaus*, *R. radiosus* and requieniids are always present in all three intervals.

In addition, the micropalaeontological content consists of *Chysalidina gradata* d'Orbigny, *Nezzazata simplex* Omara, *Trochospira avnimelechi* Hamaoui & Saint-Marc, *Biconcava bentori* Hamaoui & Saint-Marc, *Nummofallotia apula* Luperto Sinni, *Cuneolina pavonia* d'Orbigny and *Nezzazatinella picardi* (Henson).

Because of the presence of the foraminifers *C. gradata* and *T. avnimelechi* in addition to *P. fleuriaus* and *C. joannae*, the limestones of the sequence of "Archi" are assigned to the Upper Cenomanian age.



Figs. 1a, b, c, d: *Radiolites marinii*. Ventral view (a): both radial bands, protruding and rounded in shape, are visible at the middle-upper part of the individual. The area between the radial bands is characterised by large lamellae bent towards the bottom in the upper part of the individual, and by tiny lamellae in the lower part. x1. Dorsal view (b): the difference between the ornamentation of the lower and the upper part of the right valve is observed.

View of posterior (c) and anterior (d) sides where the change of the ornamentation between the lower and the upper part of the valve is well visible. x1

Sl. 1a, b, c, d: *Radiolites marinii*. Prednja stran (a): Obe radialni progi, izbočene in okrogle oblike, sta vidni na prednjem zgornjem delu osebka. Površina med radialnimi progami ima značilne velike lamele, ukrivljene navzdol na zgornjem delu primerka in tanke lamele v spodnjem delu. x1. Zadnja stran (b): razlika v ornamentaciji med spodnjim in zgornjim delom desne lupine.

Zadnja (c) in prednja (d) stran z dobro vidnimi spremembami v ornamentaciji med spodnjim in zgornjim delom lupine. x1

#### Taphonomy

The rudist fauna consists of oligotypical assemblages

of radiolitids and requieniids (Skelton & Gili, 1991). All the species of radiolitids are represented by elevator ecological morphotypes. Small bouquets of specimens

of *P. fleuriausius* are the only type of aggregation of radiolitids that is present in the sequence of "Archi". The requieniids are represented by large specimens, usually located at the sides of the small "bouquets" of *P. fleuriausius* or in thin tabular lithosomes. The requieniids are *frictional clingers* sensu Skelton & Gili (1991) and Gili *et al.* (1995).

Bioturbations are a common feature of the preservation state of most rudists found that, if present, can be observed in the upper part of the right valve. Therefore, and consistent with Philip (1972), it is possible that the lower part of the right valves was buried in the sediment, whereas the upper part was out of the sediment. The lack of bioturbations in the lower part of the right valves could also be attributed to other factors, such as the sedimentation rate and the growing rate of the individuals to avoid being buried in the sediment (Skelton *et al.*, 1995).

#### MATERIAL AND METHOD

The specimens of *R. marinii* studied in this work belong to the collection of the Dipartimento di Scienze Geologiche, Ambientali e Marine of the University of Trieste and include either adult or young specimens. In a whole, 21 specimens (16 adults and 5 young specimens) of *R. marinii* are studied in this work, with a total of 59 transverse sections. After an accurate observation of the external morphology of the right valves, an initial cut is made where a change in the ornamentation occurs (see description of the morphological variability). Afterwards, other two transverse sections are performed few centimetres below and above the initial cut.

The images of these sections are acquired and processed as follows:

- *Image acquisition*: the acquisition is made in a personal computer by means of a CCD colour camera mounted on an optical mineralogical microscope. The image is then digitised by means of an analogue-to-digital converter, i.e. Matrox Meteor.

- *Image pre-processing and features extraction*: the initial image shows 256 shades of grey in contrast with the background. The contrast is further enhanced through digital filters, thereby resulting in a final image of black objects against a white background. The format used for the images is 512 x 512 pixels. The whole system consists in an automatic programme (*WinMorfo*) that has been appropriately written in C language and Visual Basic running on a personal computer. The programme automatically extracts from each object the formal features that are considered to be characteristic, with precision levels comparable to manual or semi-automatic methods (Protopsalti, 1997).

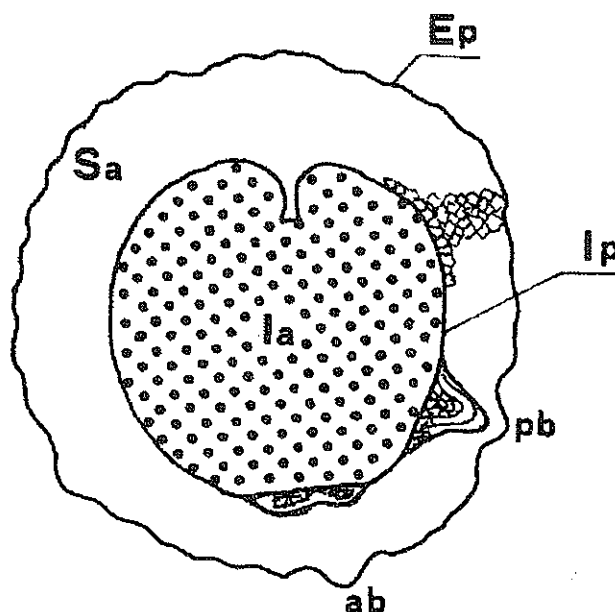


Fig. 2: Transverse section of a right valve of *Radiolites marinii*, where the measured area (*Sa*) (*Ia*) and perimeter (*Ep*) (*Ip*) are indicated. Moreover, the structures of the anterior radial band (*ab*) and the posterior radial band (*pb*) are pointed out.

Sl. 2: Prečni prerez desne lupine vrste *Radiolites marinii* z označeno merjeno površino (*Sa*) (*Ia*) in perimetrom (*Ep*) (*Ip*). Označene so tudi strukture na prednji radialni progi (*ab*) in zadnji radialni progi (*pb*).

The parameters *Ia*, *Sa*, *Ip* and *Ep* (Fig. 2) are related to the biological functions of the specimens as previously described by Cestari (1992), Reali (1992), Caffau & Pleničar (1994/95) and Caffau & Pleničar (1996). In detail, these parameters are:

- *Sa* (mm<sup>2</sup>): shell area or surface of the mantle that is responsible for the incoming water flux and the entrance of nutrients in the inner cavity.

- *Ia* (mm<sup>2</sup>): area of the inner cavity that contains the organic tissues involved in the assimilation of nutrients.

- *Ep* (mm): external perimeter that is in close correlation with the external development of the shell. It may change depending on the (kind of) interaction of the individual with the environment (i.e. the building up of protruding ribs in order to augment the surface of contact with the substratum) or with other individuals (i.e. in "bouquets" or other forms of aggregation).

- *Ip* (mm): perimeter of the inner layer of the shell.

The values of these parameters obtained for all the analysed specimens are plotted in dispersion diagrams (Fig. 3).

The images of the transverse sections of the right valves of *R. marinii* are shown in Plates 1-7 and the morphometrical values are summarised in Table 1.

| SIGLA | la (mm <sup>2</sup> ) | Sa (mm <sup>2</sup> ) | lp (mm) | Ep (mm) |
|-------|-----------------------|-----------------------|---------|---------|
| A1    | 0.979                 | 0.965                 | 3.455   | 5.525   |
| A2    | 1.386                 | 2.077                 | 4.132   | 7.877   |
| A3    | 2.137                 | 3.670                 | 5.159   | 9.208   |
| B1a   | 1.307                 | 1.903                 | 4.121   | 7.595   |
| B1b   | 1.562                 | 2.990                 | 4.516   | 8.661   |
| B2a   | 1.372                 | 2.699                 | 4.306   | 7.953   |
| B2b   | 2.221                 | 3.481                 | 5.305   | 9.963   |
| B3a   | 1.980                 | 2.102                 | 4.950   | 7.723   |
| B3b   | 2.056                 | 2.888                 | 5.065   | 8.669   |
| B3c   | 3.334                 | 4.304                 | 6.379   | 10.280  |
| C1a   | 0.874                 | 1.219                 | 3.275   | 5.201   |
| C2a   | 1.500                 | 2.289                 | 4.346   | 7.206   |
| C3a   | 1.519                 | 2.573                 | 4.300   | 7.257   |
| D1a   | 0.830                 | 1.157                 | 3.234   | 5.429   |
| D2a   | 1.601                 | 3.313                 | 4.432   | 8.760   |
| D3a   | 2.569                 | 3.965                 | 5.575   | 9.864   |
| E1a   | 0.635                 | 1.058                 | 2.763   | 5.419   |
| E2a   | 0.762                 | 2.394                 | 3.101   | 7.536   |
| F1a   | 1.015                 | 1.860                 | 3.572   | 6.451   |
| F2a   | 1.049                 | 3.274                 | 3.659   | 7.563   |
| F3a   | 1.781                 | 3.874                 | 4.864   | 8.748   |
| G1a   | 1.518                 | 2.214                 | 4.282   | 6.848   |
| G2a   | 2.263                 | 5.209                 | 9.190   | 3.082   |
| H1a   | 1.606                 | 1.970                 | 4.564   | 7.172   |
| I2a   | 1.855                 | 3.464                 | 4.845   | 8.967   |
| I3a   | 2.084                 | 3.647                 | 5.100   | 8.919   |
| I1a   | 0.851                 | 1.168                 | 3.227   | 5.614   |
| I2a   | 1.832                 | 1.629                 | 4.763   | 7.203   |
| I3a   | 1.943                 | 2.525                 | 4.954   | 8.419   |
| M1a   | 0.585                 | 1.590                 | 2.742   | 5.572   |
| M2a   | 1.193                 | 2.270                 | 4.096   | 7.196   |
| M3a   | 1.305                 | 2.436                 | 4.033   | 7.495   |
| N1a   | 1.655                 | 2.637                 | 4.504   | 7.823   |
| N2a   | 2.066                 | 2.864                 | 5.042   | 8.082   |
| N3a   | 2.535                 | 4.496                 | 5.739   | 10.028  |
| O1a   | 0.594                 | 1.604                 | 2.726   | 6.304   |
| O2a   | 1.613                 | 2.665                 | 4.448   | 8.280   |
| O3a   | 1.711                 | 2.815                 | 4.632   | 8.181   |
| P1a   | 0.427                 | 0.687                 | 2.328   | 4.404   |
| P2a   | 0.636                 | 1.527                 | 2.774   | 5.894   |
| P3a   | 0.701                 | 1.878                 | 2.997   | 6.492   |
| Q1a   | 1.346                 | 2.158                 | 4.097   | 7.790   |
| Q2a   | 1.664                 | 3.010                 | 4.517   | 8.321   |
| Q3a   | 2.991                 | 3.508                 | 6.148   | 10.062  |
| R1a   | 0.681                 | 0.822                 | 2.866   | 4.642   |
| R2a   | 1.349                 | 1.919                 | 4.065   | 7.161   |
| R3a   | 1.572                 | 2.425                 | 4.389   | 7.810   |
| S1a   | 1.184                 | 1.544                 | 3.863   | 7.214   |
| S2a   | 1.936                 | 1.833                 | 4.938   | 7.127   |
| S3a   | 2.118                 | 3.145                 | 5.150   | 8.572   |
| T1a   | 0.674                 | 0.931                 | 2.882   | 5.309   |
| T2a   | 1.180                 | 2.062                 | 3.948   | 8.422   |
| T3a   | 1.290                 | 2.535                 | 4.023   | 7.666   |
| V1a   | 0.558                 | 1.443                 | 2.604   | 5.403   |
| V2a   | 1.117                 | 2.303                 | 3.684   | 6.929   |
| V3a   | 1.663                 | 2.824                 | 4.556   | 8.398   |
| W1a   | 0.814                 | 2.004                 | 3.228   | 7.517   |
| W2a   | 1.617                 | 3.070                 | 4.567   | 9.057   |

Tab. 1: Morphometrical values obtained from transverse sections corresponding to the upper (commisure), middle (ornamentation change) and lower parts of right valves of *Radiolites marinii*.

la inner area (mm<sup>2</sup>), Sa shell area (mm<sup>2</sup>), lp inner perimeter (mm), Ep external perimeter (mm).

Tab. 1: Morfometrične vrednosti prečnih prerezov, ki ustrezajo zgornjim (komizure), srednjim (ornamentacijska sprememba) in spodnjim delom desnih lupin vrste *Radiolites marinii*.

la notranja površina (mm<sup>2</sup>), Sa površina lupine (mm<sup>2</sup>), lp notranji perimenter (mm), Ep zunanji perimenter (mm).

SYSTEMATIC PALAEOLOGY

Order HIPPURITOIDA Newell, 1965  
 Superfamily HIPPURITACEA Gray, 1848  
 Family RADIOLITIDAE d'Orbigny, 1847  
 Subfamily RADIOLITINAE d'Orbigny, 1847  
 Genus *Radiolites* Lamarck, 1848

*Radiolites marinii* CAFFAU & PLENIČAR, 1991  
 Figs. 1a-d; Pls. 1-7

**Diagnosis:** The right valve of *R. marinii* is conical in shape in young specimens (Pl. 1, Figs. 1a, b, c) and cylindro-conical in adults (Pl. 1, Figs. 4a, b). The ornamentation consists of transverse *lamae* with waving borders and longitudinal rounded ribs. The *lamae* are less prominent at the bottom and become larger, more prominent and waved towards the top of the right valve. Two of the longitudinal ribs are larger than the others and correspond to the anterior and posterior radial bands. The internal structure is a mesh of polygonal cells that is more compact at the radial bands.

The left valve is dome-like shaped and exhibits two flattened ribs that correspond to the anterior and posterior radial bands. The transverse section of the left valve shows a compact mesh of cells.

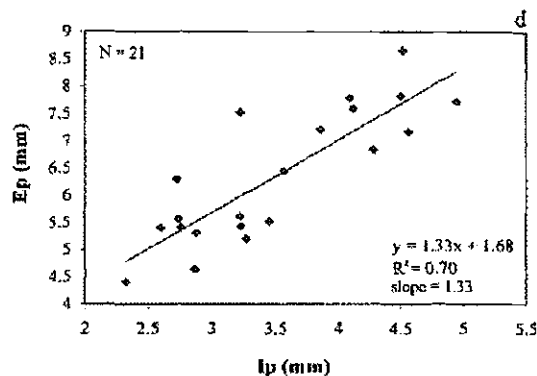
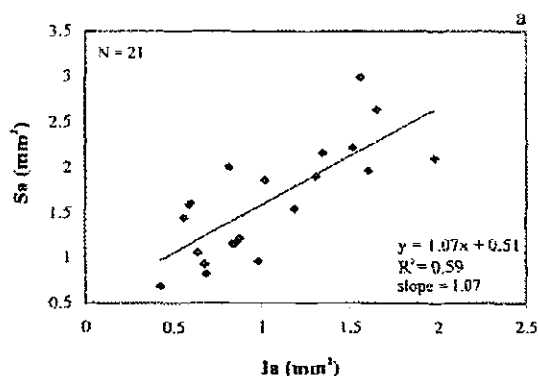
**External morphology:** *R. marinii* exhibits a large morphological variability that is clearly observed in the ornamentation of different specimens of this species.

**Attached right valve:** This valve is conical at the lower part and cylindrical at the upper part in adult specimens (Figtext 1a, b, c, d, Pl. 2, Fig. 2), whereas it is markedly conical in shape with a width aperture in young individuals (Pl. 1, Fig. 1).

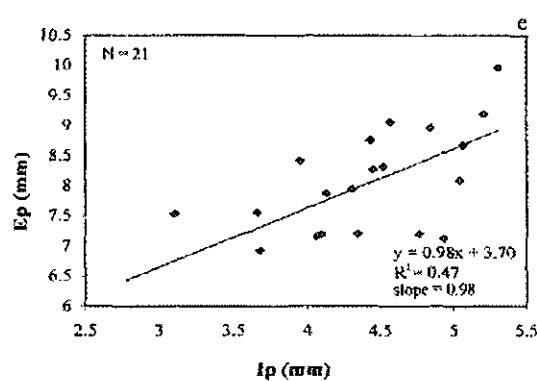
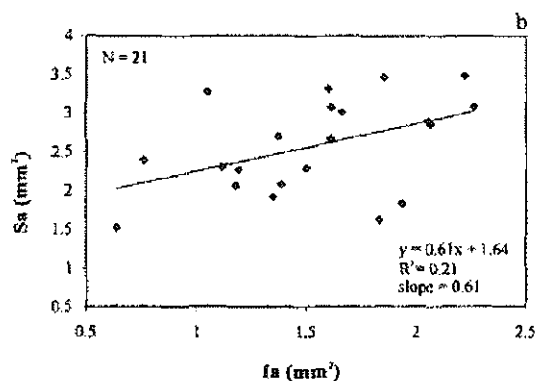
The length of these valves varies from 30 to 45 mm and the thickness of the shell is 2mm at the dorsal area and 3.5 mm at the ventral one.



1° transverse section



2° transverse section



3° transverse section

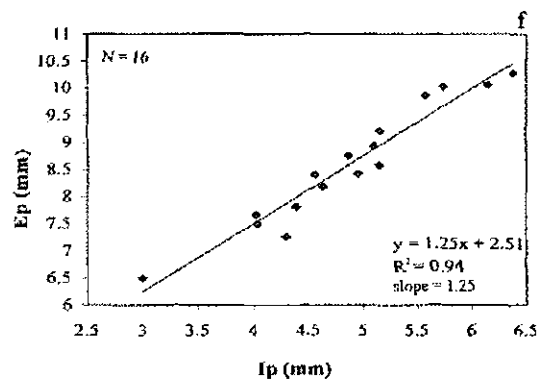
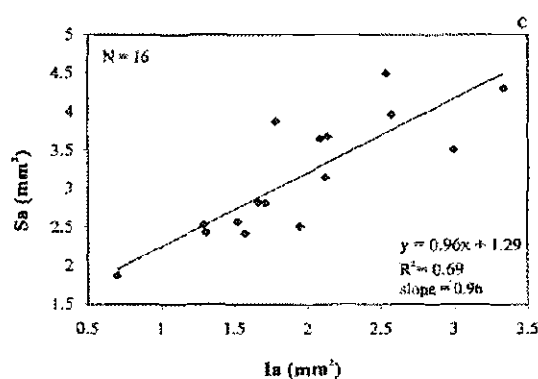


Fig. 3: Shell area (Sa) vs inner area (Ia) (3 a, b, c) and external perimeter (Ep) vs inner perimeter (Ip) (3 d, e, f) correspondig to three transverse sections from the upper (commisure), middle (ornamentation change) and lower parts of right valves of Radiolites marinii. Regression values and dispersion coefficients are shown for each plot.  
 Sl. 3: Površina lupine (Sa) proti notranji površini (Ia) (3 a, b, c) in zunanji perimetr (Ep) proti notranjemu perimetru (Ip) (3 d, e, f), ki ustrezajo trem prečnim prerezom zgornjih (komizure), srednjih (ornamentacijska sprememba) in spodnjih delov desnih lupin vrste Radiolites marinii. Regresijske vrednosti in disperzijski koeficienti so podani za vsak graf posebej.

**Ornamentation:** The right valves of adult specimens always exhibit two different morphologies. The ornamentation in the lower part of these valves consists of longitudinal ribs that are more or less prominent and robust among different specimens whereas in the upper part it is characterised by transverse and concentric *lamae* (Figtext 1a, b, c, d, Pl. 1, Figs. 4a, b).

The ornamentation in young specimens is the same as present in the lower part of the adult right valves (Pl. 1, Figs. 1a, b, Figs. 2a, b).

**Posterior and anterior sides** (Figtext 1c, d): In adult specimens the ornamentation of these sides consists of concentric *lamae* and robust longitudinal ribs that are badly preserved due to the fact that these are the areas of adherence with other individuals. In detail, thin and delicate *lamellae* alternate with robust and longitudinal ribs in the lower part. The thin *lamellae* become robust and prominent *lamae* with wavy borders in the upper part, where the longitudinal ribs are almost absent.

**Dorsal side** (Figtext 1b): The ligamental groove is hardly visible and the ornamentation is poorly defined. The *lamae* are robust and the longitudinal ribs are scarcely marked. However, the morphological difference in the ornamentation between the lower and the upper part of this side is still evident in all specimens.

**Ventral side** (Figtext 1a): From the lower part, the apex is cylindrical in shape, up to 15 mm long and 2 to 8 mm in diameter. Afterwards the shell becomes markedly conical. The ornamentation of the apex (Figtext 1a, Pl. 1, Fig. 4) consists in longitudinal and tiny ribs interrupted by *lamae* that testify the presence of megacycles, *sensu* Cestari (1992). The number of megacycles varies from 4 to 7 according to the dimensions of the specimens. The border of the *lamae* between two megacycles is wavy.

The *lamae* are more protruding in the upper part than in the lower one. Also in the upper part of the shell, megacycles are hardly seen and actually they are hidden by the well-developed *lamae* that are folded towards the bottom. The longitudinal ribs, which are in the lower part well visible, become hardly distinguishable or even disappear in the upper part of the ventral side.

The anterior radial band (**ab** in Figtext 1a, Pl. 2, Fig. 4) and posterior radial band (**pb** in Figtext 1a, Pl. 2, Fig. 4) form a deep furrow all along the right valve. A very well developed rib, cylindrical in shape, is found along the inner part of each furrow. Both radial bands are 2-3 mm wide at the commissure of the right valve (Figtext 1a). The radial bands are separated by an area with transverse *lamellae*. These *lamellae*, which are thin and very close to each other in the lower part, become more

protruding and more folded towards the bottom in the middle-upper part of the valve.

**Free left valve** (Figtext 1a, b, c, d, Pl. 2, Fig. 4): Convex valve, ornamented by very thin concentric growth lines and tiny radial *costule* that initiate in the cardinal area. In some well-preserved specimens, the border of the free valve can cover the *lamae* at the commissure of the right valve. Moreover, the left valve forms a roof-like structure that protrudes at the radial bands of the right valve. The thickness of the free valve is always less than 0.7 mm and the inner structure of the shell is compact.

**Internal characters** (Pl. 2, Fig. 1): The section of the mean cavity is circular and exhibits two slight deeps at the radial bands. The ligamental ridge is prominent and robust with a rectangular shape, slightly enlarged towards the end.

**Shell structure** (Pl. 2, Fig. 1): (a) The inner layer, generally less than 0.5 mm thick, consists of only one row of prismatic cells. (b) The outer layer, formed by two different structures: the first, a mesh of polygonal cells that is located close to the inner layer, and the second that consists of parallel rows of cells that follow a wavy trend in correspondence with the external ribs that ornament the right valve.

The internal structure at the radial bands consists of a mesh of very small prismatic cells. The pseudopilar corresponding to the anterior band is represented by a very pronounced sinus, whereas that of the posterior band consists of two sinuses. The latter are characterised by a dual structure, composed of *lamellae* and prismatic small cells.

## MEASUREMENTS: DISCUSSION

**Areal measurements:** For the first and third transverse sections (Figs. 3a, c) there is a good correlation between the parameters **Ia** and **Sa**, as shown by the respective dispersion coefficients ( $R^2$ ). In addition, for the same group of data, similar values of regression slopes can be observed. On the other hand, the data of the second transverse section (Fig. 3b) give a poor correlation between **Ia** and **Sa** and the regression slope is different from the former.

**Perimeter measurements:** Regarding the data of the first and third sections (Figs. 3d, f), the values of the dispersion coefficients ( $R^2$ ) show that there is a good correlation between the parameters **Ip** and **Ep**. There is, however, a poor correlation of these parameters for the second transverse section (Fig. 3e). Still, the values of the regression slopes are similar.

## FINAL CONSIDERATIONS AND CONCLUSIONS

The observation of the morphology of this species and the results obtained by morphometrical analysis of 21 specimens led to the following considerations:

- *R. marinii* is characterised by a clear change in the morphology of the shell ornamentation of the right valve of adult individuals.

- Morphological parameters that are involved in biological functions of this species lose their good correlation where there is a change in shell ornamentation.

Therefore, it is clear that the change in the ornamentation of the right valve represents a physiological response of the individual to an important environmental change (i.e. an enhanced rate of sedimentation or the fall of the individual from its physiological position). This response may be an abnormal secretion of calcite by the individual that alters some physiological struc-

tures (reflected in the morphological parameters) and the external ornamentation of the shell.

The considerable morphological variability of this species gives an idea of how difficult may be in some cases to look for valid features for a proper use in taxonomy.

Finally, according to the microfossil content and the fauna that is present in the sequence of "Archi" it is possible to attribute the species *R. marinii* to the Late Cenomanian.

## ACKNOWLEDGEMENTS

We are most grateful to Prof. Mario Pleničar for his helpful suggestions and pleasant discussions on the work. We also would like to thank Cristiano Landucci for the development of the software WinMorfo for the image acquisition and for his useful co-operation in the data processing stage.

## ŠTUDIJA O MORFOLOŠKI VARIABILNOSTI *RADIOLITES MARINII* CAFFAU & PLENIČAR (RADIOLITIDAE), VIŠJI CENOMANIJ, GORIŠKI KRAS, ITALIJA

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### POVZETEK

V sukcesiji od apnencev do rudistov, pripadajočih višjemu cenomaniju z območja "Archi" na jugovzhodnem Goriškem Krasu, je vrsta *Radiolites marinii* Caffau & Pleničar zelo dobro zastopana. Osebkje te vrste zaznamujeta dve morfološki ornamentaciji zunanjih površin lupin, ki bistveno ločujeta spodnji del lupine od zgornjega. Za vse odrasle osebkje so bili izdelani prečni prerezi v spodnjem (apikalnem), srednjem (kjer je opazen prehod iz prve ornamentacije v drugo) in zgornjem delu (komisura). Iz vsakega prečnega prereza sta avtorja dobila morfološke vrednosti o površini lupine (**Sa**), površini notranje votline lupine (**la**), zunanjega (**Ep**) in notranjega (**lp**) obsega lupine.

Analiza morfoloških podatkov je pokazala, da so osebkje pri prehodu iz ene ornamentacije v drugo doživeli močan biološki stres, ki je znatno vplival na normalno izločanje karbonatov.

**Ključne besede:** rudisti, morfološka variabilnost, višji cenomanij

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## PLATE 1

Figs. 1 a, b, c: *Radiolites marinii*. View of the ventral side (a), posterior side (b) and the commissure (c) of the right valve in which there is no change in the morphology between the lower and the upper part of the valve. x1

Figs. 2 a, b, c: *Radiolites marinii*. View of the ventral side (a), posterior side (b) and the commissure (c) of the right valve. The change in the morphology between the lower and the upper part of the valve is evident in this specimen. x1

Figs. 3 a, b: *Radiolites marinii*. View of the ventral side (a) and posterior side (b) of a complete specimen with both valves. x1

Figs. 4 a, b: *Radiolites marinii*. View of the ventral side (a) and posterior side (b) of the right valve in which the difference in the morphology between the lower and the upper part is clearly evident. x1

## TABLA 1

Sl. 1 a, b, c: *Radiolites marinii*. Prednja stran (a), zadnja stran (b) in komizure (c) desne lupine, kjer ni vidnih morfoloških sprememb med spodnjim in zgornjim delom lupine. x1

Sl. 2 a, b, c: *Radiolites marinii*. Prednja stran (a), zadnja stran (b) in komizure (c) desne lupine. Morfološke spremembe med spodnjim in zgornjim delom lupine pri tej vrsti so vidne. x1

Sl. 3 a, b: *Radiolites marinii*. Prednja stran (a) in zadnja stran (b) celotnega osebka z obema lupinama. x1

Sl. 4 a, b: *Radiolites marinii*. Prednja stran (a) in zadnja stran (b) desne lupine, kjer so dobro vidne morfološke spremembe med spodnjim in zgornjim delom lupine. x1

## PLATE 2

Fig. 1: *Radiolites marinii*. Thin transverse section of the right valve. Structure of polygonal cells that are smaller at the radial bands pb and ab. x3.5

Fig. 2: *Radiolites marinii*. View of the ventral side of the right valve in which the difference in the morphology between the lower and the upper part is clearly evident. x1

Fig. 3: *Radiolites marinii*. View of the ventral side of the right valve. x1

Fig. 4: *Radiolites marinii*. View of the ventral side of the left valve and part of the right valve in which the lamae and the radial bands are well preserved. Note the good preservation state of the area of contact between the right and the left valves. x1

## TABLA 2

Sl. 1: *Radiolites marinii*. Tanek prečni prerez desne lupine. Struktura poligonalnih celic, ki so manjše pri radialnih progah pb in ab. x3.5

Sl. 2: *Radiolites marinii*. Prednja stran desne lupine, kjer so dobro vidne morfološke razlike med spodnjim in zgornjim delom lupine. x1

Sl. 3: *Radiolites marinii*. Prednja stran desne lupine. x1

Sl. 4: *Radiolites marinii*. Prednja stran leve lupine in del desne lupine, pri kateri so lamae in radialne proge dobro ohranjene. Opazna je visoka stopnja ohranjenosti stične površine med desno in levo lupino. x1

## PLATE 3

Figs. A1-B3c: *Radiolites marinii*. Transverse section of the right valves subjected to morphometrical analysis. Scale bar = 1cm.

## TABLA 3

Sl. A1-B3c: *Radiolites marinii*. Prečni prerezi desnih lupin, ki so bili morfometrično obdelani. Merilo = 1cm.

## PLATE 4

Figs. C1a-F3a: *Radiolites marinii*. Transverse section of the right valves subjected to morphometrical analysis. Scale bar = 1cm.

## TABLA 4

Sl. C1a-F3a: *Radiolites marinii*. Prečni prerezi desnih lupin, ki so bili morfometrično obdelani. Merilo = 1cm.

## PLATE 5

Figs. G1a-M3a: *Radiolites marinii*. Transverse section of the right valves subjected to morphometrical analysis. Scale bar = 1cm.

## TABLA 5

Sl. G1a-M3a: *Radiolites marinii*. Prečni prerezi desnih lupin, ki so bili morfometrično obdelani. Merilo = 1cm.

## PLATE 6

Figs. N1a-Q3a: *Radiolites marinii*. Transverse section of the right valves subjected to morphometrical analysis. Scale bar = 1cm.

## TABLA 6

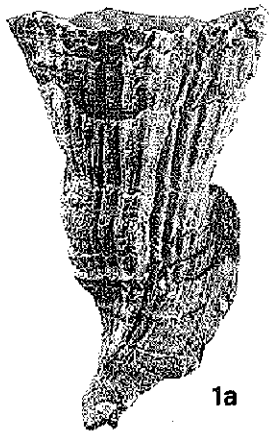
Sl. N1a-Q3a: *Radiolites marinii*. Prečni prerezi desnih lupin, ki so bili morfometrično obdelani. Merilo = 1cm.

## PLATE 7

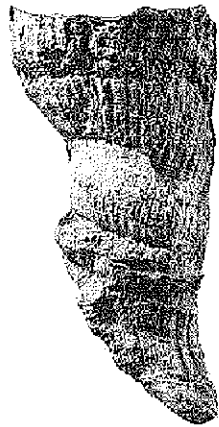
Figs. R1a-W2a: *Radiolites marinii*. Transverse section of the right valves subjected to morphometrical analysis. Scale bar = 1cm.

## TABLA 7

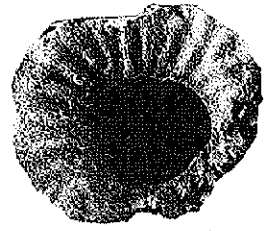
Sl. R1a-W2a: *Radiolites marinii*. Prečni prerezi desnih lupin, ki so bili morfometrično obdelani. Merilo = 1cm.



1a



1b



1c



2a



2b



2c



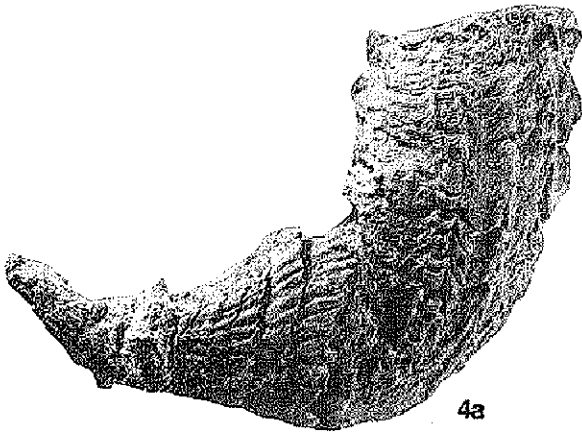
3a



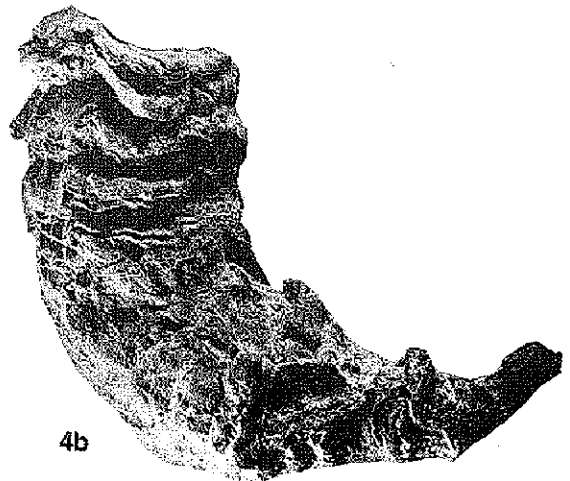
3b



3c



4a



4b

PLATE 1 / TABLA 1



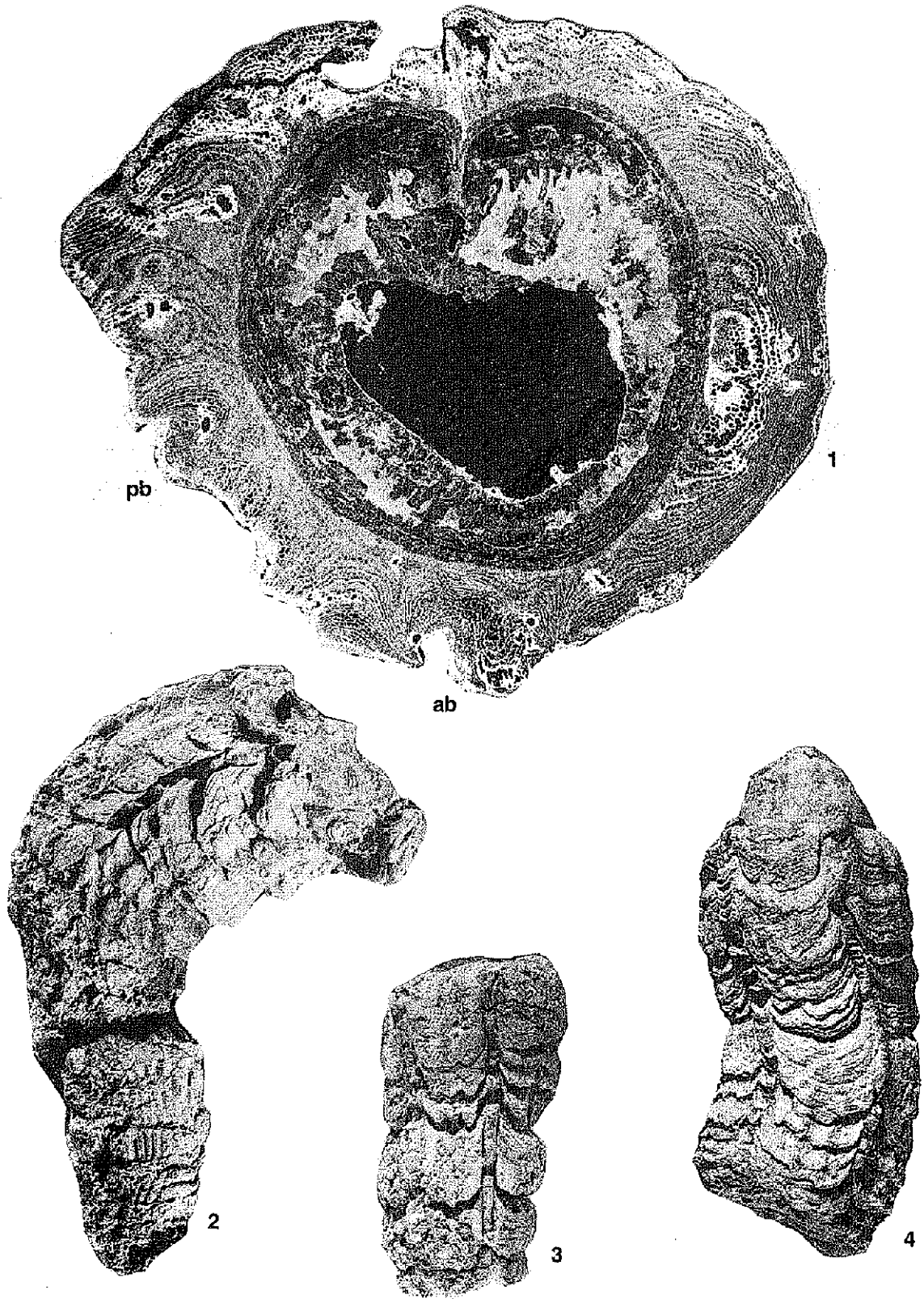


PLATE 2 / TABLA 2

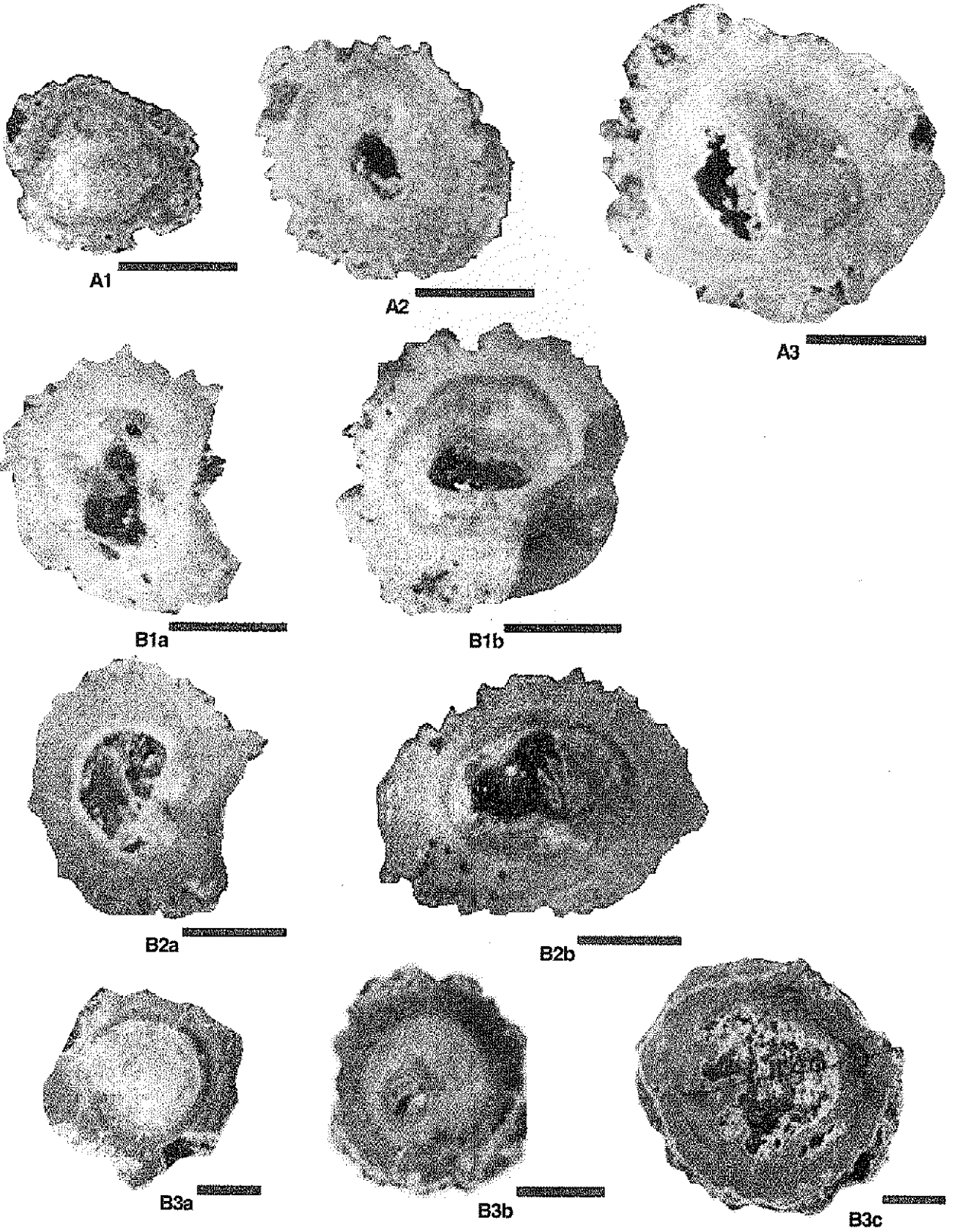


PLATE 3 / TABLA 3

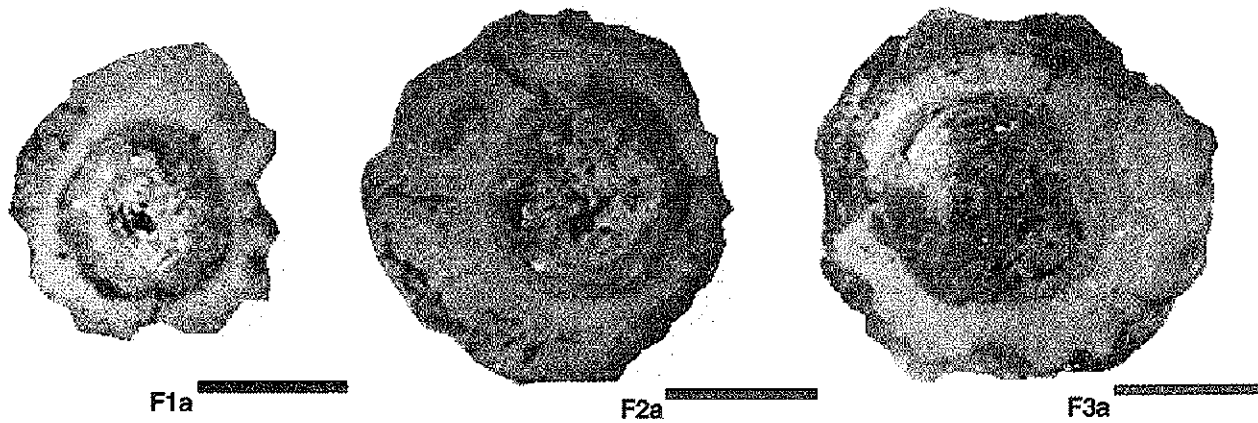
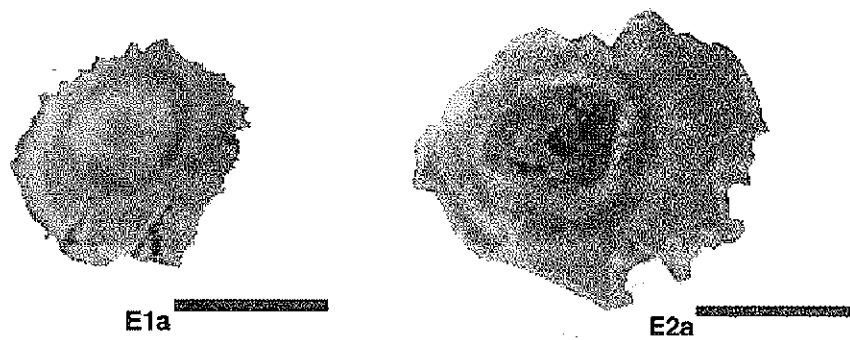
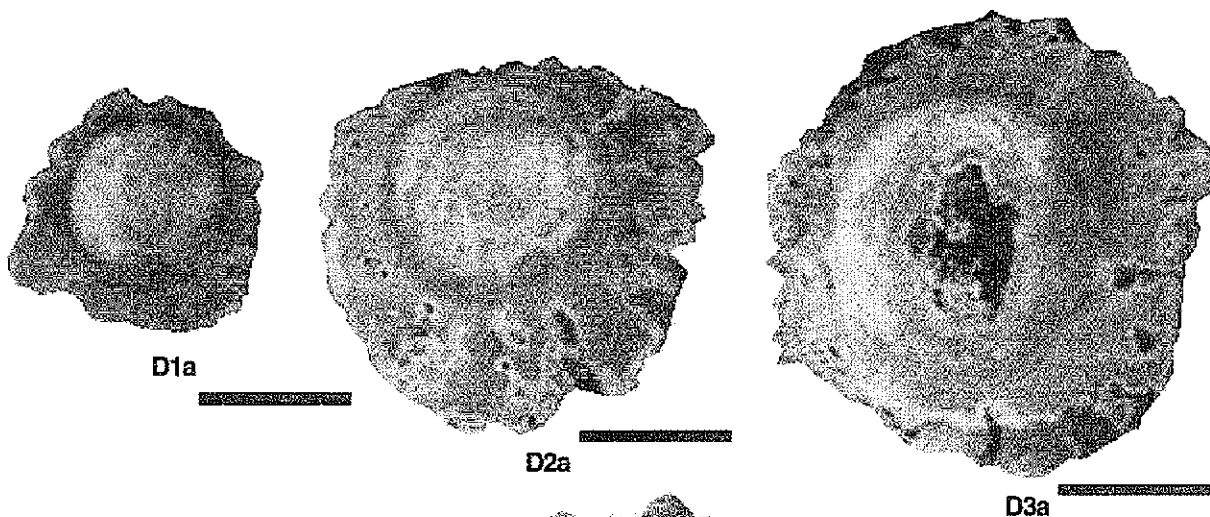
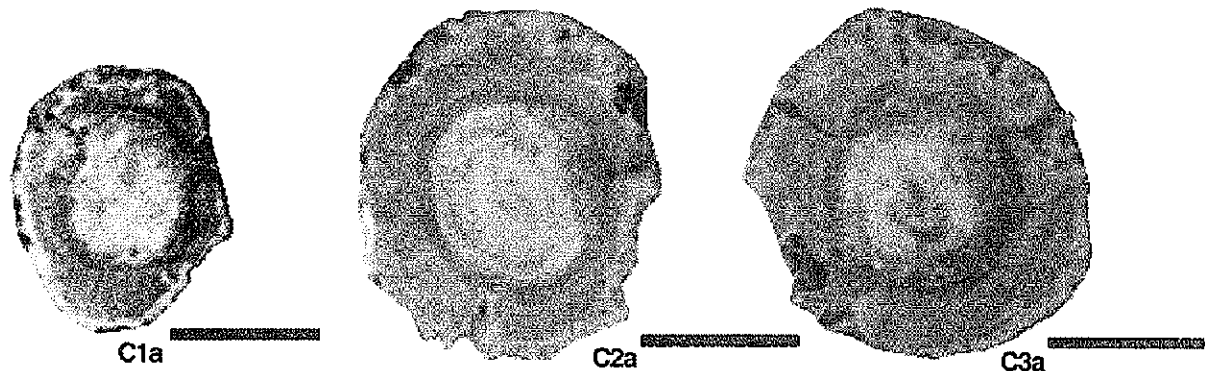


PLATE 4 / TABLA 4

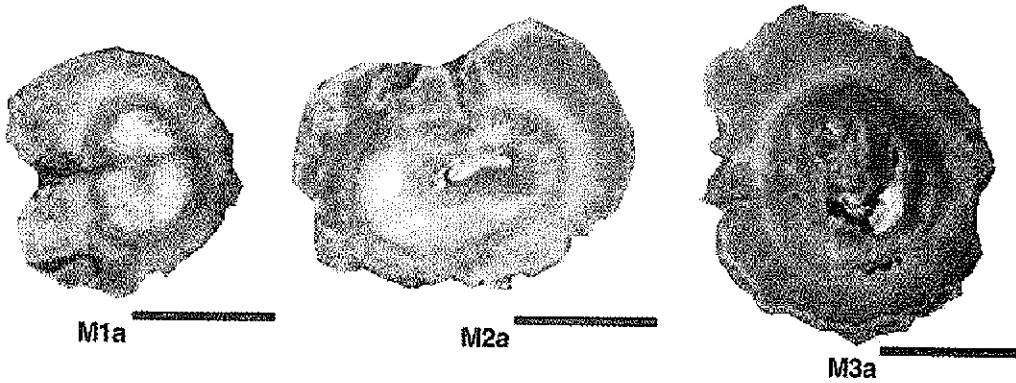
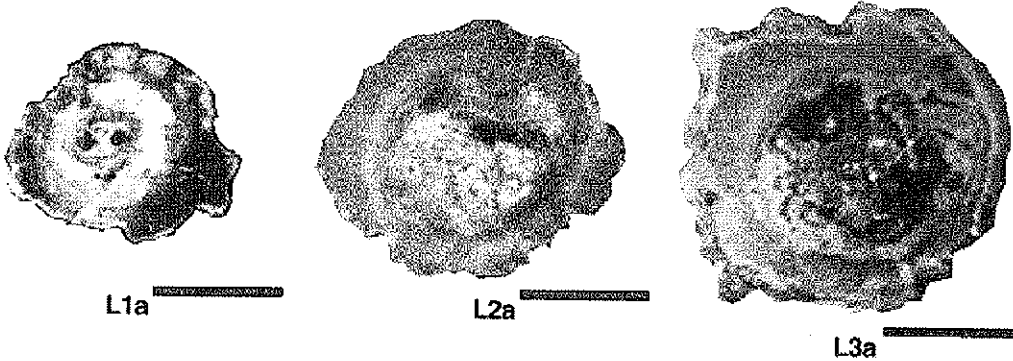
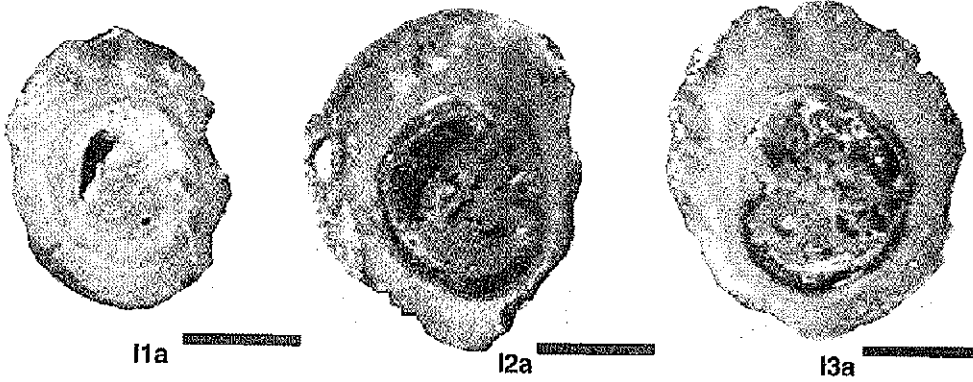
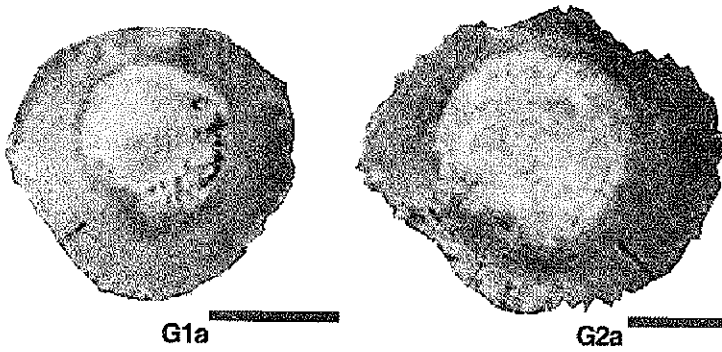


PLATE 5 / TABLA 5

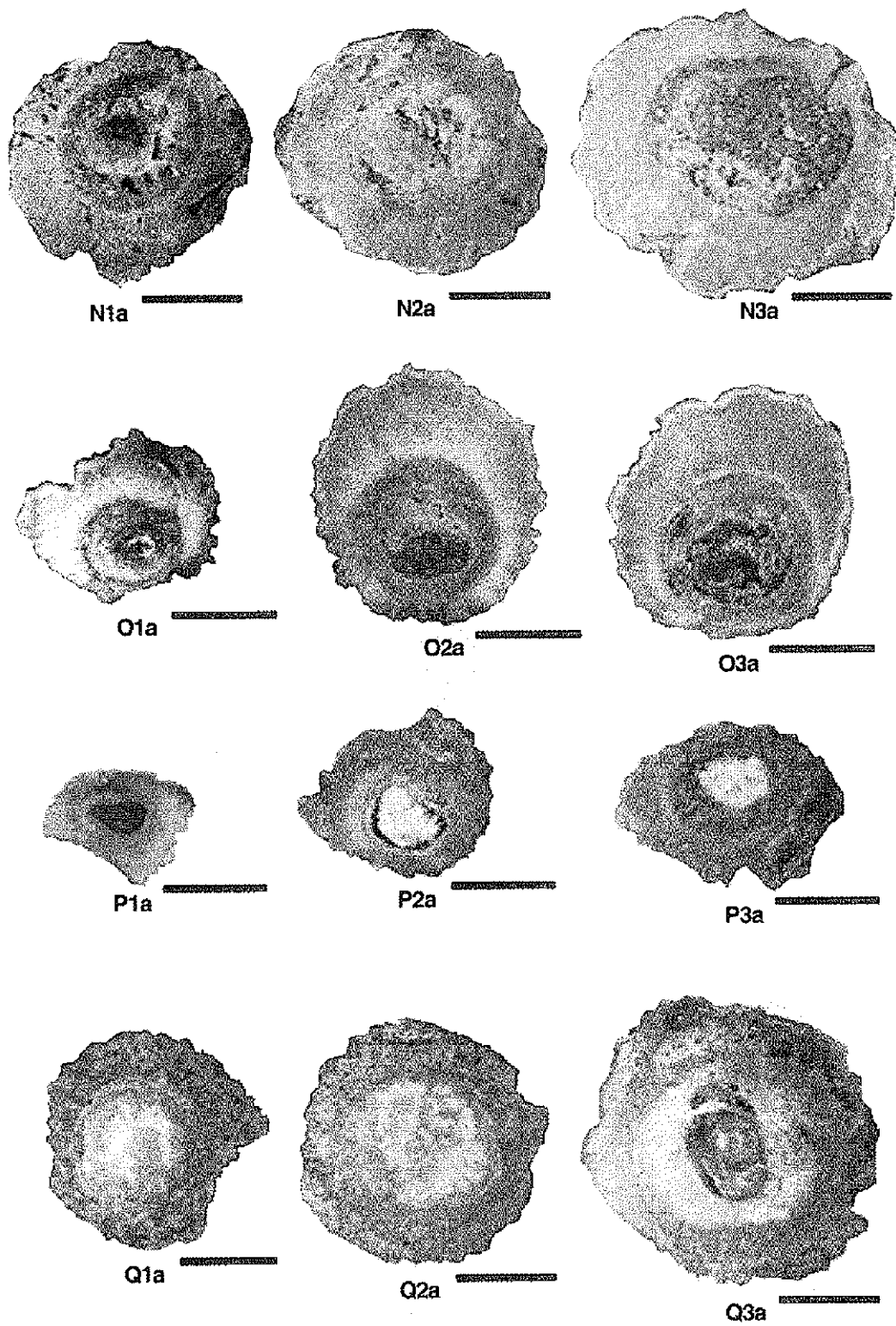


PLATE 6 / TABLA 6



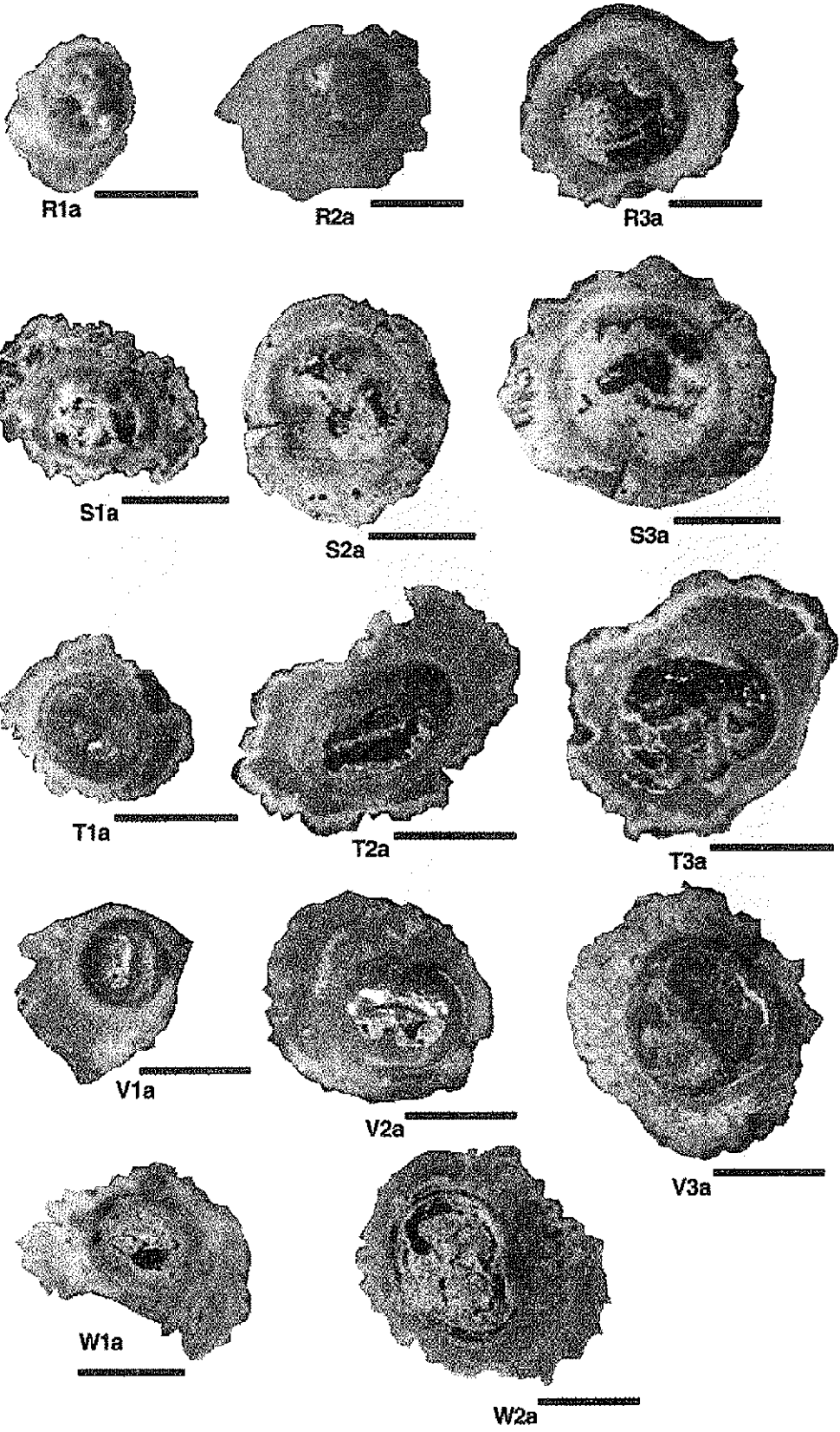


PLATE 7 / TABLA 7



FAVNA

FAUNA

FAUNA



## GNEZDILKE POPOGORIŠČNEGA HABITATA NA PETRINJSKEM KRASU

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Kocjančiči 18, 6276 Pobegi

## IZVLEČEK

V letih 1998-99 je bila na popogoriščnem rastišču ruja in žajblja popisana ptičja skupnost. Vrstna pestrost in gnezditvena gostota ptic sta tu večja kot v okoliških habitatih, kar pomeni, da je požar ugodno vplival na grmiščno ornitofavna.

**Ključne besede:** ptice gnezdilke, vegetacijska sukcesija, Petrinjski kras

## UVOD

Za slovenske submediteranske vegetacijske razmere je sestoj ruja (*Cotinus coggygria*) in žajblja (*Salvia officinalis*) dandanes nekaj izjemnega. Pojavlja se na kraških tleh predvsem na nekaj let starih pogoriščih in zato na razmeroma majhnih površinah. V kultivirani pokrajini velja za pustoto. Življenjska doba takšnega sestoja ni znana, zagotovo pa je le faza v ciklusu vegetacijskega nasledstva. Tipološko ga smemo prištevati k tipu nizkega in odprtega sredozemskega grmičevja (*t.im. garigi*), katerega nastanek je odvisen od vrste tal in prsti ter pašnega in požarnega režima v mnogoterih različicah.

S popisom sem nameraval ugotoviti, katere vrste ptic gnezdi v takšnem pogoriščnem habitatu, poraslem z rujem in žajbljem. Ugotovitve naj bi pomagale ovrednotiti pomen požarnega gospodarjenja v kultivirani pokrajini, kar je še posebno aktualno v sedanjih postkulturnih razmerah, ko se zaradi zastale paše kraški svet zarašča (Geister, 1998).

Ornitofavna slovenskega krasa je v domačem strokovnem slovstvu razdrobljeno in temu primerno pomanjkljivo obdelana. Le območje Čičarije in Kraškega roba sta temeljiteje popisala Marčeta (1992) in Gjerkeš (1995, 1996).

Uredništvo ornitološke revije *Acrocephalus* je v letu 1999 načrtovalo posebno številko, posvečeno ornitofavni krasa, v kateri naj bi bile objavljene najnovejše ra-

ziskave ptičjega sveta s tega favnistično in vegetacijsko zelo svojskega območja. Po nasilni odstavitvi glavnega in odgovornega urednika in solidarnostnem odstopu celotnega uredniškega odbora junija 1999 se je avtor odločil za objavo svojega kraškega prispevka v reviji *Annales*.

## OPIS OBMOČJA

Rastišče ruja in žajblja na Petrinjskem krasu je dvodelno; razteza se na vsaki strani makadamske ceste Petrinje - Podgorje. Vzhodni del je velik 350 x 900 m, zahodni 500 x 700 m, tako da skupaj merita 66,5 ha (sl. 1). Rastišče leži na pobočju, ki se od gradišča Soligrad vzpenja proti Gavju (177 m). V popisnem območju izrazito prevladuje sestoj ruja in žajblja, od grmovja se na robovih pojavljajo mladi grmi navadnega brina (*Juniperus communis*), od drevesnih vrst pa raztreseno rastejo črni bor (*Pinus nigra*), kraški gaber (*Carpinus orientalis*) in mali jesen (*Fraxinus ornis*). Semtertja so vidne apnenčaste goličave. vzdolž severovzhodne strani območja poteka kolovoz, ob njem sta dva opuščena kamnoloma, v prvem je odlagališče odpadkov, v drugem policijsko strelišče. Po jugozahodni strani območje prehaja v travnike, zaraščajoče se z brinom (vzhodni predel), oziroma v listnati gozd (zahodni predel). Na severozahodni strani mejita oba dela popisnega območja na gozd črnega bora. Medtem ko je zahodni del kljub napetosti dokaj raven, je vzhodni zaznamovan z večjo

vrtičo na zahodnem robu. Prek območja vzporedno potekata dva daljnovoda.

Za popolnejšo oceno ornitološke pomembnosti popogoriškega habitata, poraslega z rujem in žajbljem, bi tukajšno ptičjo skupnost moral primerjati s ptičjimi skupnostmi okoliških habitatov: travniškega z opuščeni in predvsem s črnim trnom poraslimi vrtičami, travniškega, poraslega z brinjem, in grmovnatega, v katerem prevladujeta brin in ruj. Leta 1999 je bil takšen primerjalni popis narejen na travniku, poraslem z rujem in brinom (brez žajblja), enake velikosti kot vzhodni raziskovalni predel, na katerega tudi meji. Takšno poraščenost štejem za naslednjo stopnjo vegetacijske sukcesije.

## METODA

V zemljevid popisnega območja sem vnašal vse na terenu pojoče samce, ki so bili osnova za oceno števila gnezdečih parov. Domnevne gnezditve so bile v večini primerov tudi potrjene z opazovanjem za zarod skrbečih staršev. Da sem osebek štel za gnezdilca, je moral biti odkrit vsaj trikrat. Porazdelitev pojočih samcev je bila kartirana *in situ*.

Po kartirni metodi sem popisoval leta 1998 8. 5., 12. 5., 31. 5 in 5. 6., leta 1999 pa 27. 5., 3. 6. in 16. 6.

## REZULTATI

Rezultati popisa so zbrani v tabeli 1.

Tab. 1: Sestava pojočih samcev na rastišču ruja in žajblja (66,5 ha) na Petrinjskem krasu v letih 1998-99 (n - število pojočih samcev;  $\Sigma$  - število pojočih samcev v obeh predelih, GG - gnezditvena gostota).

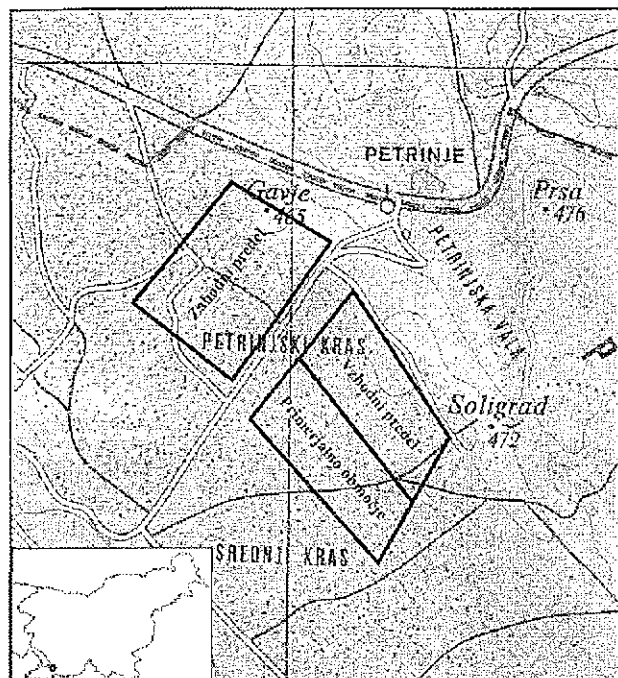
Tab. 1: Structure of singing males in the wig tree and sage habitat (66.5 ha) in the Petrinje Karst during 1998-99 (n - number of singing males,  $\Sigma$  - number of singing males in both parts, GG - breeding density).

| vrsta / species               | zahodni del / western part |    | vhodni del / eastern part |    | skupaj total |          | GG     |
|-------------------------------|----------------------------|----|---------------------------|----|--------------|----------|--------|
|                               | n                          | n  | n                         | n  | $\Sigma$     | $\Sigma$ | GG     |
| leto / year                   | 98                         | 99 | 98                        | 99 | 98           | 99       | g/10ha |
| <i>Alauda arvensis</i>        | 1                          | 1  | 2                         | 3  | 3            | 4        | 0,5    |
| <i>Anthus campestris</i>      | -                          | -  | 2                         | 1  | 2            | 1        | 0,2    |
| <i>Turdus merula</i>          | -                          | -  | 2                         | 1  | 2            | 1        | 0,2    |
| <i>Saxicola torquata</i>      | -                          | 1  | 2                         | 3  | 2            | 4        | 0,5    |
| <i>Saxicola rubetra</i>       | -                          | -  | 1                         | 2  | 1            | 2        | 0,2    |
| <i>Hypollais polyglotta</i>   | -                          | 1  | 1                         | 1  | 1            | 2        | 0,2    |
| <i>Sylvia cantillans</i>      | -                          | 3  | 1                         | -  | 1            | 3        | 0,3    |
| <i>Sylvia curruca</i>         | 2                          | -  | -                         | -  | 2            | -        | 0,3    |
| <i>Sylvia communis</i>        | 4                          | 2  | 5                         | 3  | 9            | 5        | 1,1    |
| <i>Sylvia atricapilla</i>     | 1                          | 5  | 1                         | 1  | 2            | 6        | 0,6    |
| <i>Phylloscopus collybita</i> | 1                          | 1  | 1                         | 1  | 2            | 2        | 0,3    |
| <i>Lanius collurio</i>        | 1                          | -  | 3                         | 1  | 4            | 1        | 0,4    |
| <i>Fringila coelebs</i>       | -                          | 1  | -                         | -  | -            | 1        | 0,2    |
| <i>Chloris chloris</i>        | -                          | -  | -                         | 1  | -            | 1        | 0,2    |
| <i>Emberiza citrinella</i>    | 3                          | 1  | -                         | -  | 3            | -        | 0,5    |
| <i>Emberiza hortulana</i>     | -                          | -  | 4                         | 2  | 4            | 2        | 0,5    |
| <i>Miliaria calandra</i>      | 1                          | 2  | 6                         | 4  | 7            | 6        | 1,0    |
| skupaj / total                | 14                         | 18 | 31                        | 24 | 45           | 42       |        |

Tab. 2: Sestava pojočih samcev na primerjalnem območju (31,5 ha), poraslem z rujem in brinom, leta 1999.

Tab. 2: Structure of singing males in a comparative area (31.5 ha) overgrown with wig and juniper trees in 1999.

| vrsta / species            | št. parov / No. pairs |
|----------------------------|-----------------------|
| <i>Alauda arvensis</i>     | 1                     |
| <i>Saxicola torquata</i>   | 2                     |
| <i>Parus caeruleus</i>     | 1                     |
| <i>Sylvia curruca</i>      | 1                     |
| <i>Sylvia communis</i>     | 2                     |
| <i>Lanius collurio</i>     | 2                     |
| <i>Emberiza citrinella</i> | 3                     |
| <i>Miliaria calandra</i>   | 6                     |
| skupaj / total             | 18                    |

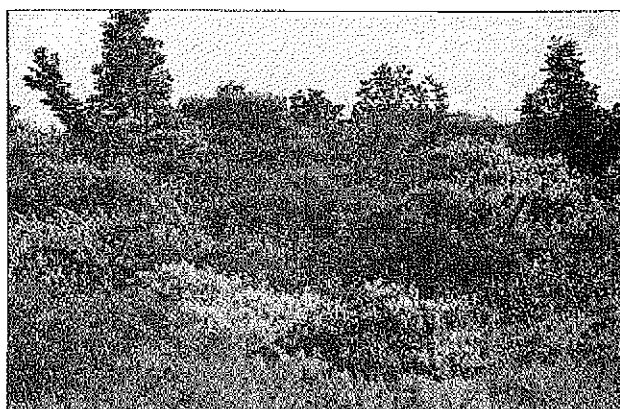


Sl. 1: Popisno območje na popogoriščnem habitatu ruja in žajblja (zahodni predel, vzhodni predel in primerjalno območje) na Petrinjskem krasu.

Fig. 1: The surveyed area in a post-conflagrated wig tree and sage habitat (western part, eastern part and a comparative area) in the Petrinje Karst.

#### RAZPRAVA

V primerjavi s sosednim vzhodnim predelom raziskovanega območja je bilo v primerjalnem območju v letu 1999 popisanih za četrtno manj pojočih samcev. Na odprtih travnikih (travnikih, ki niso poraščeni s sklenjenim grmovjem) je bila vrstna pestrost manjša, le osem vrst v primerjavi s trinajstimi na rujevo-žajbljevem rastišču (vzhodni predel), zato pa gostota petih v obeh prebivališčih živečih vrst ptic različna: dveh nekoliko večja (rjavega srakoperja *Lanius collurio* in velikega strnada *Miliaria calandra*), treh pa manjša (poljskega škranca *Alauda arvensis*, kar je presenetljivo, prosnika *Saxicola torquata* in sive penice *Sylvia communis*). Glede na to, da se je število pojočih samcev v vzhodnem predelu v dveh letih zmanjšalo, v zahodnem povečalo, v celoti pa ostalo skorajda nespremenjeno, je mogoče sklepati, da je za letne razlike odgovorno le notranje preseljevanje. Zato lahko obravnavani habitat štejejo za delno izoliran življenjski prostor, z nekaterimi težko razločljivimi posebnostmi (karkršna je npr. pojavljanje škrancev). Kljub majhnim absolutnim in velikim relativnim zneskom, ki omogočajo pretirane interpretacije števil, popogoriščni habitat ruja in žajblja lahko štejejo za sorazmerno bogato življenjsko okolje ptic na slovenskem krasu.



Sl. 2: Popogoriščni habitat ruja in žajblja na Petrinjskem krasu spomladi 1998 (Foto: I. Geister).

Fig. 2: Post-conflagrated wig tree and sage habitat in the Petrinje Karst in spring 1998 (Photo: I. Geister).

Seveda pa s tem še ni rečeno, da je kras optimalni življenjski prostor tamkaj živečih ptic. Kljub temu da so siva penica, veliki strnad in vrtni strnad *Emberiza hortulana* za kras tipične vrste, je njihova gostota v primerjavi z gostoto v optimalnih prebivališčih zelo nizka. Gostota sive penice dosega v mešanih grmiščnih sestojih do 10 parov na 10 ha, v kultivirani pokrajini pa zdrsne na 0,5 parov na 10 ha (podatki veljajo za Veliko Britanijo) (Hagemeljer & Blair, 1997). V obravnavani združbi ruja in žajblja dosega 1,1 para na 10 ha (1998), kar je za tip odprte grmovne združbe bržkone malo.

Veliki strnad dosega na senožetih 3,3 para na 10 ha in na ekstenzivnih pašnikih 0,7 para na 10 ha (podatka izvirata iz Francije) (Bauer & Glutz von Blotzheim, 1988). Na petrinjskem pogorišču, poraslem z rujem in žajbljem, ostaja z gostoto 1 para na 10 ha (1998) pri dnu lestvice.

Še najbolj so razčlenjeni podatki za vrtnega strnada iz južne Francije, kjer dosega naslednje gostote: a) na suhih travnikih z redkim grmičevjem 0,2-0,4, b) na odprtih suhih travnikih z obdelanimi vrtačami do 1,7 in c) na travnikih z raztresenimi skupinami listnatega grmovja in brinja do 2,5 para na 10 ha (Bauer & Glutz von Blotzheim, 1998). Na našem kraškem rastišču ruja in žajblja doseže gostoto komaj 0,5 para na 10 ha (1998), to pa je približek mediteranskim vrednostim za travnata prebivališča.

Nemara preseneča pojavljanje rumenega strnada *Emberiza citrinella collybita*, medtem ko navzočnost poljskega škranca glede na tamkajšno manjšo gostoto neprepričljivo pojasnujejo bližnji travniki. Za izrazite robne vrste veljajo v danem primeru rjava cipa *Anthus campestris* (kamnolom), mlinarček *Sylvia curruca* (borovje) in vrbja listnica *Phylloscopus collybita* (gradnova hosta). Zaradi pritlehne rasti mladega ruja je pokritost tal zelo velika. Tako ni čudno, da prevladujejo talni gnezdilci (škranjci, cipe, strnadi in cmokači), pa tudi

penice in srakoperji si spletejo gnezdo v pritlehnem vejevju.

Primerjava podatkov o številu pojočih samcev v zaporednih dveh letih kaže z vidika dolgoročnejših vegetacijsko nasledstvenih nagnenj bolj ali manj pričakovane rezultate. Tako je v letu 1999 v primerjavi z letom 1998 upadlo predvsem število sivih penic in rjavih srakoperjev, torej vrst, ki živijo v nesklenjenem grmovju, naraslo pa je število črnoglavk *Sylvia atricapilla* in taščičnih penic *Sylvia cantillans*, torej vrst, ki živijo v sklenjenem grmovju. Četudi je preučevano ob-

dobje odločno prekratko za to, da bi se lahko izrisalo daljnosežnejše dogajanje, pa je vendarle jasno, da se grmovje popogoriščnega habitata počasi spreminja iz bolj odprtega v bolj ali manj zaprt prostor.

Čeprav v obravnavanem habitatu ne gnezdi nobena takšna vrsta, ki ne bi gneznila tudi v okoliških habitatih, je vpliv požara na vrstno pestrost in gostoto gnezdečih vrst očiten, saj sta pestrost in delno tudi gostota vrst na rastišču ruja in žajblja večja kot v neposredni okolici. Seveda pa kakšnih posplošenih spoznanj zaradi fragmentarnosti habitata ni pričakovati.

## BREEDING BIRDS OF A POST-CONFLAGRATED HABITAT IN THE PETRINJE KARST

Iztok GEISTER

Kocjanciči 18, 6276 Pobegi

### SUMMARY

*In 1998-1999, the breeding birds of some 66.5 ha large former conflagration, now overgrown with wig tree *Cotinus coggygria* and sage *Salvia officinalis*, were surveyed near the village of Petrinje in the Slovene Karst. 17 breeding species were established, with 45 singing males in 1998 and 42 singing males in 1999. The most common breeders were the Common Whitethroat *Sylvia communis* and Corn Bunting *Miliaria calandra*. All the surveyed species were also recorded in the neighbouring habitats, although in smaller numbers.*

*The survey has shown that the post-conflagrated wig tree and sage habitat has a favourable effect on the breeding birds' diversity and density.*

**Key words:** breeders, vegetational succession, Petrinje Karst

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## ORNITOFAVNA ZGORNJEGA DELA DOLINE REKE IN BLIŽNJE OKOLICE

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## IZVLEČEK

Med letoma 1994 in 1999 je bilo v dolini Reke in bližnji okolici opazovanih 147 vrst ptic, od tega 85 vrst potrjenih in 19 verjetnih gnezditk ter 25 vrst preletnikov; 78 vrst ptic v dolini prezimuje. Zabeleženo je bilo naraščanje populacije pojočih koscev *Crex crex*, opaženi sta bili tudi veliki gnezditveni gostoti rjavega srakoperja *Lanius collurio* ter velikega strnada *Miliaria calandra*. Obrežje Reke je edina gnezditvena lokacija čebelarja *Merops apiaster* v JZ Sloveniji. V kamnolomu nad Ilirsko Bistrico je bil opazovan skalni brglez *Sitta neumayer* - prvo opazovanje te ptice v Sloveniji. Gnezditvene habitate neposredno ob Reki in trstičja ogrožajo hidromelioracijski posegi v strugo.

**Ključne besede:** ornitologija, dolina Reke, Primorska, JZ Slovenija

## UVOD

Dolina Reke je spričo naravnega bisera Škocjanskih jam, v katere Reka ponikne, in nepreglednega Snežniškega masiva neupravičeno zapostavljena v pogledu naravoslovnih raziskovanj.

Dosedanje floristične in favnistične raziskave so dokaj bome. Šele v zadnjem času so bile opravljene nekatere floristične raziskave, ki so deloma zajele tudi floro in vegetacijo doline (Jogan *et al.*, 1996; Seliškar & Vreš, 1995). Podobno je s favno kačjih pastirjev (Šalamun *et al.*, 1997), metuljev (Čelik, 1994; Čelik & Rebušek, 1996; Verovnik, 1997) in sesalcev (Trilar, 1997). Na pobudo Zavoda za varovanje naravne in kulturne dediščine Nova Gorica je bila izdelana inventarizacija favne zgornjega toka reke Reke, ki je zajela raziskave vrbnic (Plecoptera), muh poplesovalk (Empididae, Diptera), dvoživk (Amphibia) in ptic (Aves), vendar rezultati inventarizacije za vse skupine niso popolni (Sivec *et al.*, 1996). Na posameznih lokalitetah je bila na pobudo istega zavoda inventarizirana flora in vegetacija (Seliškar & Vreš, 1995). Razmeroma slabo je poznana tudi ornitofavna, saj je intenzivneje raziskovana šele v zadnjih nekaj letih (Polak, 1997). Šele nočni popisi koscev *Crex crex* v zadnjem času so opozorili na mednarodni ornitološki pomen območja (Trontelj, 1995,

1996), katerega del je vključen med ornitološko pomembna območja Slovenije (IBA). Namen članka je prispevati k poznavanju ptic zgornjega dela doline Reke in bližnje okolice.

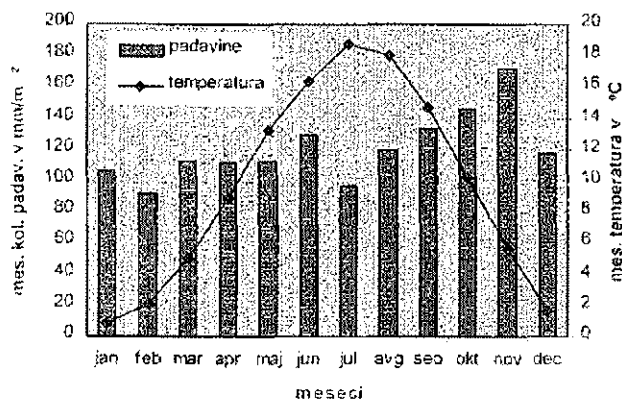
## RAZISKOVANO OBMOČJE

Dolina Reke se razteza v smeri SZ-JV v JZ delu Slovenije, samo porečje pa se opira na neprepustne terciarne flišnate plasti (laporji in peščenjaki), ki sestavljajo brkinsko sinklinalo. Na SV krilo brkinske sinklinala pa se nariva snežniški masiv, sestavljen iz zgornje- in spodnjekrednih apnencev ter dolomitov in se nad dolino pokaže z markantno stopnjo nad zgornjim tokom Reke, kjer je tudi največ ravnega sveta v celotnem porečju Reke. Tu sta se izoblikovali dve fluvialni terasi, kjer je ozemlje, ki ga poplave Reke ne dosežejo, izkoriščeno za njive in travnike (Pavlovec & Pleničar, 1980; Rojšek, 1987). Reko napajajo vode iz snežniškega masiva po desnih kraških pritokih (Bistrica, Podstenjšček). Neposredno ob Reki najdemo kvartarne rečne naplavine, glavnino doline pa tvori terciarni fliš (Pavlovec & Pleničar, 1980). Zgornji del doline Reke leži na nadmorski višini 420-400 m. V njem se je razvila Ilirska Bistrica (pribl. 4900 preb.), največje naselje celotne doline in porečja Reke ter sedež občine, ki med drugim

zajema celoten zgornji del doline.

Dolini daje glavno obeležje reka Reka, tipična kraška reka in najdaljša ponikalnica v Sloveniji. Izdolbla je enega najbolj zanimivih naravnih pojavov - Škocjanske jame, ki so vpisane v seznam svetovne naravne in kulturne dediščine pri UNESCO. Za Reko je značilno izredno kolebanje vodnega pretoka tako med letom kot tudi med posameznimi meseci, saj razmerje med najnižjim in najvišjim pretokom presega 1:3.000. Ima submediteranski pluvio-nivalni rečni režim z vplivi kraške retinence oziroma najvišjo vodno gladino jeseni (november), najnižjo pa poleti (avgust). Vsakoletne poplave so pravilo (Rojšek, 1996).

Bližina morja pomeni milejšo klimo, saj povprečna letna temperatura zraka niha med 9,6 in 12°C (Hidrometeorološki zavod Republike Slovenije, 1995b; Pučnik, 1974) (Ilirska Bistrica, 414 m n.m.v.; Sl. 1). Značilnost lokalne klime so tudi velika temperaturna kolebanja zlasti v zimskih mesecih, ko pride zaradi izpostavljenosti doline proti S do nenadnega vdora hladnega zraka s snežniškega masiva z značilno burjo (Klemencič, 1959). Dogaja se, da mešanje morskih in kontinentalnih zračnih gmot ob menjavanju vlažnega ter toplega jugozahodnika in mrzlega severozahodnika vodi v nastajanje žleda (Rojšek, 1987). Kljub temu se povprečna temperatura zraka tudi najhladnejših mesecev ne spusti pod 0°C (januar 1,6°C). Prve slane se pojavljajo ob koncu oktobra in v prvi polovici novembra, zadnje pa ob koncu marca oziroma v začetku aprila. V dolini je pozimi temperaturna inverzija pogost pojav.



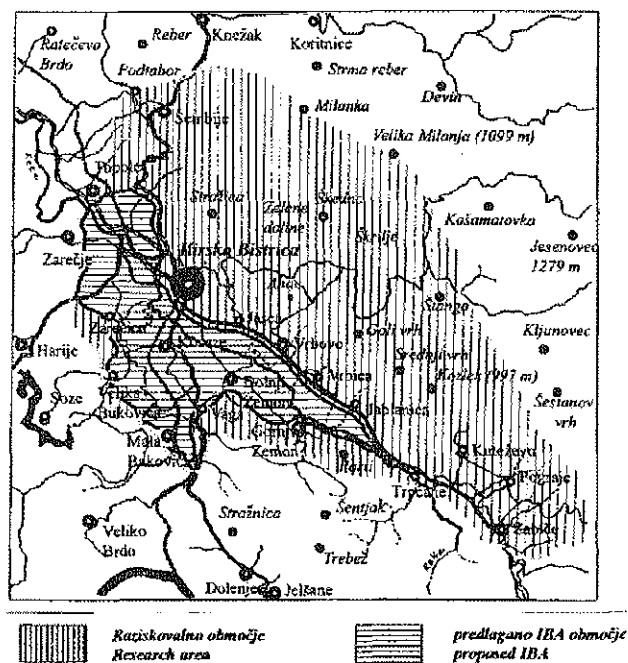
Sl. 1: Povprečna mesečna količina padavin in povprečna mesečna temperatura zraka na meteorološki postaji Ilirska Bistrica v obdobju 1961-1990 (Hidrometeorološki zavod Republike Slovenije, 1995a, b; Pučnik, 1974).

Fig. 1: Mean monthly precipitation rate and mean monthly air temperature at the Ilirska Bistrica Weather Station in the 1961-1990 period (Hydrometeorological Institute of the Republic of Slovenia, 1995a, b; Pučnik, 1974).

Dolina prejme v povprečju 1447 mm padavin, največ oktobra (146 mm) in novembra (172 mm), najmanj pa februarja (92 mm) in julija (97 mm) (Hidrometeorološki zavod Republike Slovenije, 1995a).

Reka priteče v zgornji del doline iz toploljubnega bukovega gozda z jesensko vilovino (*Seslerio - Fagetum*), ki prevladuje v zgornjem toku Reke. V širših stranskih jarkih in ob sami Reki uspeva združba velikega jesena in plemenitih listavcev (*Aceri - Fraxinetum*), na pobočjih, obrnjenih proti severu, pa bukov gozd z bekico (*Luzulo - Fagetum*) (Seliškar & Vreš, 1995). Dolina se pri vasi Zabiče razširi v obdelovalne površine in travnike z visoko pahovko (*Arrhenantheretum s.lato*), modro stožkovko (*Molinetum caeruleae s.lato*) ter pokončne stoklase in srednjega trpotca (*Bromo - Plantaginetum mediae*), slednji že zunaj poplavnih voda. Prekinjajo jih visokostebelni senožetni sadovnjaki, drevoredi, žive meje, poti in melioracijski kanali. Po dolini se fragmentarno pojavljajo še posamezna okna trstičja (*Phragmitetum australis*), ostrega šašja (*Carietum gracilis s.lato*) in volkovja (*Nardetum s.lato*).

Travnati svet doline z desnega brega Reke omejuje gozd črnega gabra z jesensko vilovino (*Seslerio - Ostryetum*), ki ga ponekod prekinjajo zaplate suhih kraških travišč nizkega šaša in skalnega glavinca (*Carici humilis - Centaurietum rupestris*) ter oklasnice in dlakavega gadnjaka (*Danthonio - Scorzoneretum villosae*), z leve pa večinoma gozd belega gabra (*Carpinetum s.lato*), gradna (*Quercus petraea*) in cera (*Quercus cerris*).



Sl. 2: Dolina Reke z bližnjo okolico.

Fig. 2: Upper Reka valley and neighbouring area.

Erodირani rečni bregovi in manjša prodišča ob Reki so rezultat njenega hudourniškega značaja. Strmo odsekani rečni bregovi se pojavljajo bolj ali manj po obrežju celotnega toka Reke, vsakoletne poplave pa jih sproti oblikujejo in spreminjajo.

V zgornjem delu so tudi prodišča večinoma nestabilna, na njih pa prevladujejo nitrofilne in konkurenčno najbolj sposobne rastlinske vrste. Po toku navzdol pa so bolj izoblikovana z že značilno vegetacijo iz zvez *Bidention tripartiti* (s prevladujočimi vrstami *Bidens tripartita*, *Epilobium hirsutum*, *Polygonum minus*, *P. persicaria* in *Rumex obtusifolius*), *Nanocyperion* (*Cyperus fuscus*) in združbe *Junco - Menthetum longifoliae* (*Mentha longifolia*, *Juncus inflexus*).

V zgornjem toku je pas obrežne vegetacije razmeroma ozek, prevladujeta pa bela vrba (*Salix alba*) in jelša (*Alnus glutinosa*); jelševje (*Alnetum glutinosae*) je razvito le fragmentarno. Po dolini navzdol pa se postopoma širi in v ulekninah pasu poplavnega območja so razviti logi, kjer se omenjenima drevesnima vrstama pridružijo še robinija (*Robinia pseudoaccacia*) in lipovec (*Tilia cordata*) ter grmovnice rdeča vrba (*Salix purpurea*), trdoleska (*Euonymus europaea*), rdeči dren (*Cornus sanguinea*), leska (*Coryllus avellana*) in dobrovita (*Viburnum lantana*) (Seliškar & Vreš, 1995). Najbolj prodorni rastlini obrežij sta topinambur (*Helianthus tuberosus*) in orjaška rozga (*Solidago gigantea*), ki ponekod (zlasti po toku navzdol) popolnoma izpodrineta

druge vrste (*Epilobium hirsutum*, *Mentha longifolia* ...).

Fitogeografsko uvrščamo dolino Reke v submediteransko območje (Wraber, 1969) oziroma brkinski distrikt (Zupančič et al., 1987).

Mozaična razporeditev travnikov, visokostebelnih senoženih sadovnjakov, njiv, drevoredov in pasov grmovja ter pestra izbira poljščin govori o ekstenzivni rabi zemljišč. Lastniki le-teh so skoraj izključno zasebniki, ki še vedno bolj ali manj tradicionalno gospodarijo s svojimi površinami. Intenzivnejšo izrabo površin pa do neke mere onemogočajo tudi vsakoletne poplave, zlasti v neposredni bližini Reke. Tako poplavni del območja zasebniki večinoma le kosijo, tu in tam pa se košenice zaradi nedonosnosti oziroma opustitve košnje in paše zaraščajo.

## MATERIALI IN METODE

Terensko delo je zajemalo v glavnem opazovanja od leta 1994 do leta 1999. Uporabljal sem daljnogledne različnih povečav, opazovanja pa so zajemala zgornji tok doline Reke, ki sem ga v smeri vzhod-zahod omejil z vasema Zabiče in Podtabor, proti severu z Gurami, proti jugu pa s črto Trpčane-Gornji in Dolnji Zemon-Zarečica-Zarečje (Sl. 2). Popisovanje ptic je tako zajemalo dva krajinsko, geološko in vegetacijsko jasno ločena predela: flišnato dolino ter suhe kraške travnike nad dolino Reke.

**Tab. 1: Seznam opazovanih vrst. Kategorije ogroženosti po Bračko et al., 1994; primerjava statusa vrst po Geister, 1995; Polak, 1997; Sivec et al., 1995; Sovinc 1994;\* Bračko & Grošelj, 1994; P: vrsta je opazovana na preletu; Ph: vrsta je opazovana v prehranjevalnem habitatu; Pg: poletni gost, spolno nezreli osebki letujejo izven gnezdišč; Z: vrsta v dolini Reke prezimuje; Gn?: vrsta je verjetni gnezdilec; Gn: vrsta je potrjen gnezdilec.**

**Tab. 1: List of the observed species. Threat status according to Bračko et al., 1994; comparison of the status according to Geister, 1995; Polak, 1997; Sivec et al., 1995; Sovinc 1994;\* Bračko & Grošelj, 1994; P: species observed during migration; Ph: species observed in feeding habitat; Pg: summer visitor, immature individuals summering outside breeding area, Z: species overwintering in the Reka valley; Gn?: probable breeder; Gn: confirmed breeder.**

| št. | znanstveno ime                    | ogroženost | status |      |                    |             |                  |
|-----|-----------------------------------|------------|--------|------|--------------------|-------------|------------------|
|     |                                   |            | ZOAS   | OA S | Sivec et al., 1995 | Polak, 1997 | Surina (to delo) |
| 1   | <i>Acanthis cannabina</i>         |            | Z      | Gn   |                    |             |                  |
| 2   | <i>Accipiter gentilis</i>         | V 3.c      | Z      | Gn   |                    |             | Z                |
| 3   | <i>Accipiter nisus</i>            | V 3.c      | Z      | Gn   |                    |             | Z                |
| 4   | <i>Acrocephalus arundinaceus</i>  | E 2.c      |        |      |                    |             | Gn               |
| 5   | <i>Acrocephalus palustris</i>     |            |        | Gn   | Gn?                | Gn          | Gn               |
| 6   | <i>Acrocephalus schoenobaenus</i> | V 3.a      |        |      |                    |             | P                |
| 7   | <i>Acrocephalus scirpaceus</i>    | V 3.a      |        |      |                    |             | P                |
| 8   | <i>Actitis hypoleucos</i>         | E 2.c      |        |      |                    |             | Gn?              |
| 9   | <i>Aegithalos caudatus</i>        |            | Z      |      | Gn                 |             | Z, Gn            |
| 10  | <i>Alauda arvensis</i>            | R 4.b      |        |      | Gn?                | Gn          | Gn               |
| 11  | <i>Alcedo atthis</i>              | E 2.c      |        | Gn   | Gn                 | Gn          | Z, Gn            |
| 12  | <i>Alectoris graeca</i>           | E 2.b      |        |      |                    |             | Z, Gn?           |
| 13  | <i>Anas acuta</i>                 |            |        |      |                    |             | P, Z             |
| 14  | <i>Anas platyrhynchos</i>         |            | Z      | Gn   | Gn?                |             | Z, Gn            |

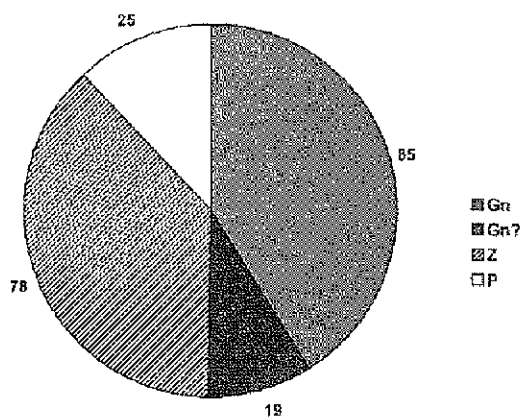
|    |                                      |          |   |     |     |     |        |
|----|--------------------------------------|----------|---|-----|-----|-----|--------|
| 15 | <i>Anas querquedula</i>              | E 2.a    |   |     |     |     | P      |
| 16 | <i>Anser anser</i>                   |          | Z |     |     |     |        |
| 17 | <i>Anthus campestris</i>             |          |   | Gn  |     |     | Gn?    |
| 18 | <i>Anthus pratensis</i>              |          | Z |     |     |     |        |
| 19 | <i>Anthus spinoleta</i>              |          | Z |     |     |     |        |
| 20 | <i>Anthus trivialis</i>              |          |   | Gn  | Gn? |     | Gn     |
| 21 | <i>Apus apus</i>                     |          |   | Gn  |     |     | Gn     |
| 22 | <i>Aquila chrysaetos</i>             | V 3.a    |   |     |     |     | Gn     |
| 23 | <i>Ardea cinerea</i>                 | R 4.b    | Z |     | P   | Gn? | Z, Gn? |
| 24 | <i>Asio otus</i>                     |          | Z |     |     |     |        |
| 25 | <i>Athene noctua</i>                 | E 2.c    | Z | Gn  |     | Gn? | Gn     |
| 26 | <i>Aythya nyroca</i>                 | E 2.a    |   |     |     |     | P      |
| 27 | <i>Bombycilla garrulus</i>           |          |   |     |     |     | P, Z*  |
| 28 | <i>Bubo bubo</i>                     | E 2.c    | Z | Gn  |     |     | Gn     |
| 29 | <i>Buteo buteo</i>                   |          | Z | Gn  | Gn? |     | Z, Gn  |
| 30 | <i>Caprimulgus europaeus</i>         | E 2.c    |   | Gn  |     |     | Gn     |
| 31 | <i>Carduelis carduelis</i>           |          | Z | Gn  | Gn? |     | Z, Gn  |
| 32 | <i>Carduelis flammea</i>             |          |   |     |     |     | Z      |
| 33 | <i>Carduelis spinus</i>              |          | Z |     |     |     |        |
| 34 | <i>Carpodacus erythrinus</i>         |          |   | Gn? |     |     |        |
| 35 | <i>Certhia brachydactyla</i>         |          | Z |     |     |     | Z, Gn? |
| 36 | <i>Charadrius dubius</i>             | V 3.c    |   |     |     |     | Gn     |
| 37 | <i>Chloris chloris</i>               |          | Z |     |     | Gn  | Z, Gn  |
| 38 | <i>Ciconia ciconia</i>               | E 2.b    |   |     |     |     | P      |
| 39 | <i>Cinclus cinclus</i>               | V 3.b    |   |     |     |     | Z, Gn  |
| 40 | <i>Circus gallicus</i>               | E 2.a    |   | Gn  |     |     | P      |
| 41 | <i>Circus aeruginosus</i>            |          |   |     | P   |     |        |
| 42 | <i>Circus cyaneus</i>                |          |   |     |     |     | P, Z   |
| 43 | <i>Coccythraustes coccythraustes</i> |          | Z |     |     | Gn  | P, Z   |
| 44 | <i>Columba livia</i>                 | E 2.b    | Z | Gn  |     |     | Z, Gn  |
| 45 | <i>Columba palumbus</i>              |          |   |     |     |     | Gn     |
| 46 | <i>Corvus corax</i>                  |          | Z | Gn  |     |     | Gn     |
| 47 | <i>Corvus corone cornix</i>          |          | Z | Gn  | Gn? | Gn  | Gn     |
| 48 | <i>Corvus monedula</i>               |          | Z |     |     |     |        |
| 49 | <i>Coturnix coturnix</i>             | V 3.c    |   | Gn  | Gn? | Gn  | Gn     |
| 50 | <i>Crex crex</i>                     | E 2.c    |   | Gn  |     |     | Gn     |
| 51 | <i>Cuculus canorus</i>               |          |   | Gn  | Gn? |     | Gn?    |
| 52 | <i>Delichon urbica</i>               |          |   | Gn  | Gn  |     | Gn     |
| 53 | <i>Dendrocopos major</i>             |          | Z | Gn  | Gn? | Gn  | Gn     |
| 54 | <i>Dendrocopos minor</i>             |          | Z |     |     |     |        |
| 55 | <i>Egretta garzetta</i>              |          |   |     |     |     | P      |
| 56 | <i>Emberiza cia</i>                  |          | Z | Gn  |     |     | Gn     |
| 57 | <i>Emberiza cirius</i>               |          | Z |     |     |     | Gn     |
| 58 | <i>Emberiza citrinella</i>           |          | Z | Gn  |     | Gn  | Gn     |
| 59 | <i>Erithacus rubecula</i>            |          | Z | Gn  | Gn  |     | Gn     |
| 60 | <i>Falco columbarius</i>             |          |   |     |     |     | Z      |
| 61 | <i>Falco peregrinus</i>              | E 2.c    | Z |     |     |     | Z, Gn  |
| 62 | <i>Falco subbuteo</i>                | V 3.c    |   |     | Ph  |     | Gn?    |
| 63 | <i>Falco tinnunculus</i>             | V 3.c    | Z |     |     |     | Gn     |
| 64 | <i>Falco vespertinus</i>             |          |   |     | P   |     | P      |
| 65 | <i>Ficedula hypoleuca</i>            |          |   |     |     |     | P      |
| 66 | <i>Fringilla coelebs</i>             |          | Z | Gn  | Gn? |     | Z, Gn  |
| 67 | <i>Fringilla montifringilla</i>      |          | Z |     |     |     |        |
| 68 | <i>Gallinago gallinago</i>           | E 2.a    | Z |     |     |     | Z, Gn? |
| 69 | <i>Gallinula chloropus</i>           |          |   | Gn  | Gn? |     | Gn     |
| 70 | <i>Garrulus glandarius</i>           |          | Z | Gn  |     |     | Z, Gn  |
| 71 | <i>Grus grus</i>                     |          |   |     |     |     | P      |
| 72 | <i>Gyps fulvus</i>                   | Ex 1.1.a |   |     |     |     | P      |
| 73 | <i>Hippolais icterina</i>            |          |   |     |     |     | P      |

|     |                                |          |   |    |     |     |           |
|-----|--------------------------------|----------|---|----|-----|-----|-----------|
| 74  | <i>Hippolais polyglotta</i>    |          |   |    |     |     | Gn        |
| 75  | <i>Hirundo rustica</i>         |          |   | Gn | Gn  |     | Gn        |
| 76  | <i>Ixobrychus minutus</i>      | E 2.a    |   |    |     | Gn? | Gn?       |
| 77  | <i>Jynx torquilla</i>          | V 3.c    |   | Gn | Gn? | Gn  | Gn        |
| 78  | <i>Lanius collurio</i>         | R 4.b    |   | Gn | Gn  | Gn  | Gn        |
| 79  | <i>Lanius excubitor</i>        | Ex 1.1.a | Z |    |     |     | Z         |
| 80  | <i>Lanius minor</i>            | E 1.2.c  |   |    |     | Gn  |           |
| 81  | <i>Larus cachinans</i>         | R 4.a    |   |    |     |     | P, Z      |
| 82  | <i>Larus ridibundus</i>        | V 3.a    | Z |    |     |     | P, Z      |
| 83  | <i>Locustella naevia</i>       | V 3.b    |   |    |     |     | P         |
| 84  | <i>Loxia curvirostra</i>       |          | Z |    |     |     |           |
| 85  | <i>Luscinia megarhynchos</i>   |          |   | Gn |     |     | Gn        |
| 86  | <i>Merops apiaster</i>         | E 1.2.a  |   |    |     | Gn  | Gn        |
| 87  | <i>Miliaria calandra</i>       | V 3.c    |   | Gn | Gn  | Gn  | Gn        |
| 88  | <i>Monticola saxatilis</i>     | V 3.b    |   | Gn |     |     | Gn        |
| 89  | <i>Monticola solitarius</i>    | R 4.a    |   |    |     |     | Gn?       |
| 90  | <i>Motacilla alba</i>          |          |   | Gn | Gn? | Gn  | Gn        |
| 91  | <i>Motacilla cinerea</i>       |          | Z | Gn | Gn? | Gn  | Z, Gn     |
| 92  | <i>Muscicapa striata</i>       |          |   | Gn | Gn  |     | Gn        |
| 93  | <i>Nycticorax nycticorax</i>   | E 1.2.a  |   |    | Gn? | Gn? | P, Gn?    |
| 94  | <i>Oenanthe oenanthe</i>       |          |   | Gn |     |     | Gn        |
| 95  | <i>Oriolus oriolus</i>         |          |   | Gn | Gn  |     | Gn        |
| 96  | <i>Otus scops</i>              | E 2.c    |   |    |     | Gn? | Gn        |
| 97  | <i>Parus ater</i>              |          | Z | Gn | Gn  |     | Z, Gn     |
| 98  | <i>Parus caeruleus</i>         |          | Z | Gn | Gn  | Gn  | Z, Gn     |
| 99  | <i>Parus cristatus</i>         |          | Z |    |     |     |           |
| 100 | <i>Parus major</i>             |          | Z | Gn | Gn  | Gn  | Z, Gn     |
| 101 | <i>Parus palustris</i>         |          | Z |    |     |     | Z, Gn     |
| 102 | <i>Passer domesticus</i>       |          | Z |    | Gn  |     | Z, Gn     |
| 103 | <i>Passer montanus</i>         |          | Z |    | Gn  | Gn  | Z, Gn     |
| 104 | <i>Pernis apivorus</i>         | V 3.c    |   |    |     |     | P         |
| 105 | <i>Phalacrocorax carbo</i>     |          |   |    |     |     | P, Z      |
| 106 | <i>Phasianus colchicus</i>     |          |   |    |     |     | Z, Gn     |
| 107 | <i>Phoenicurus ochruros</i>    |          |   | Gn |     |     | Z, Gn     |
| 108 | <i>Phoenicurus phoenicurus</i> | E 2.c    |   | Gn |     |     |           |
| 109 | <i>Phylloscopus collybita</i>  |          |   | Gn | Gn? | Gn  | Gn        |
| 110 | <i>Pica pica</i>               |          | Z | Gn |     |     | Z, Gn     |
| 111 | <i>Picus canus</i>             | V 3.c    |   |    |     | Gn  | Gn        |
| 112 | <i>Picus viridis</i>           | V 3.c    |   |    |     |     | Gn?       |
| 113 | <i>Plectrophenax nivalis</i>   |          |   |    |     |     | Z         |
| 114 | <i>Porzana porzana</i>         | E 2.a    |   |    |     |     | Gn?       |
| 115 | <i>Prunella collaris</i>       |          | Z |    |     |     |           |
| 116 | <i>Prunella modularis</i>      |          | Z |    |     |     | Z         |
| 117 | <i>Pyrrhula pyrrhula</i>       |          | Z |    | Gn? |     | Z, Gn     |
| 118 | <i>Rallus aquaticus</i>        | E 2.c    |   |    |     |     | Gn?       |
| 119 | <i>Regulus ignicapillus</i>    |          | Z |    |     |     | Z, Gn     |
| 120 | <i>Regulus regulus</i>         |          | Z |    | Gn? |     |           |
| 121 | <i>Remiz pendulinus</i>        | V 3.b    |   |    |     |     | Gn?       |
| 122 | <i>Saxicola rubetra</i>        | E 2.c    |   | Gn | Gn? |     | Gn        |
| 123 | <i>Saxicola torquata</i>       |          |   |    |     | Gn  | Gn        |
| 124 | <i>Serinus serinus</i>         |          |   | Gn | Gn? | Gn  | Gn        |
| 125 | <i>Sitta europaea</i>          |          | Z |    |     | Gn  | Z, Gn     |
| 126 | <i>Sitta neumayer</i>          |          |   |    |     |     | P         |
| 127 | <i>Streptopelia decaocto</i>   |          | Z | Gn | Gn? |     | Z, Gn     |
| 128 | <i>Streptopelia turtur</i>     |          |   | Gn |     |     |           |
| 129 | <i>Strix aluco</i>             |          | Z |    | Gn? |     | P, Z, Gn? |
| 130 | <i>Sturnus vulgaris</i>        |          | Z |    | Gn  | Gn  | Z, Gn     |
| 131 | <i>Sylvia atricapilla</i>      |          |   | Gn | Gn? | Gn  | Z, Gn     |
| 132 | <i>Sylvia borin</i>            | R 4.b    |   | Gn |     |     | Gn        |

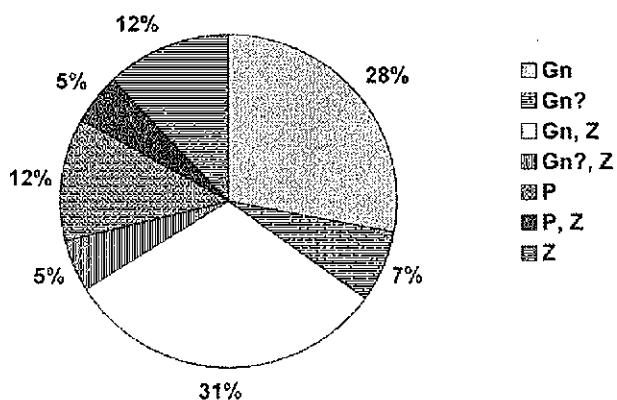
|     |                                |       |   |     |     |    |        |
|-----|--------------------------------|-------|---|-----|-----|----|--------|
| 133 | <i>Sylvia communis</i>         | V 3.c |   | Gn  |     |    | Gn     |
| 134 | <i>Sylvia curruca</i>          |       |   | Gn  |     |    | Gn     |
| 135 | <i>Sylvia nisoria</i>          | V 3.b |   | Gn  |     |    | Gn     |
| 136 | <i>Tachybaptus ruficollis</i>  |       |   |     | Gn  |    | Z, Gn  |
| 137 | <i>Tetrastes bonasia</i>       |       | Z | Gn? |     |    |        |
| 138 | <i>Tichodroma muraria</i>      | R 4.a | Z |     |     |    | P, Z   |
| 139 | <i>Tringa ochropus</i>         |       |   |     |     |    | P      |
| 140 | <i>Troglodytes troglodytes</i> |       | Z | Gn  | Gn? | Gn | Z, Gn  |
| 141 | <i>Turdus merula</i>           |       | Z | Gn  | Gn? | Gn | Z, Gn  |
| 142 | <i>Turdus philomelos</i>       |       |   | Gn  | Gn? |    | Gn     |
| 143 | <i>Turdus pilaris</i>          |       | Z |     |     |    | Z      |
| 144 | <i>Turdus viscivorus</i>       |       | Z |     | Gn? |    | Z, Gn? |
| 145 | <i>Tyto alba</i>               | E 2.c |   |     |     |    | Z, Gn  |
| 146 | <i>Upupa epops</i>             | E 2.c |   |     | Gn? |    | Gn     |
| 147 | <i>Vanellus vanellus</i>       |       |   |     |     |    | Z      |

Tab. 2: Število vseh opazovanih vrst in njihov status.  
 Tab. 2: Number of all the observed species and their threat status.

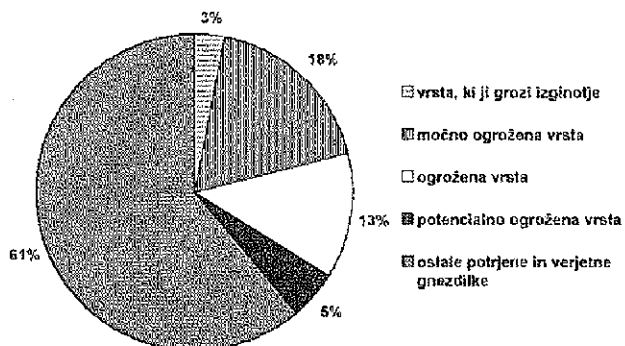
| status ptice | št. vrst |
|--------------|----------|
| Gn           | 41       |
| Gn?          | 11       |
| Gn, Z        | 44       |
| Gn?, Z       | 8        |
| P            | 17       |
| P, Z         | 8        |
| Z            | 18       |
| skupaj       | 147      |



Sl. 4: Absolutno število opazovanih vrst glede na njihov status.  
 Fig. 4: Absolute number of the observed species on view of their status.



Sl. 3: Delež opazovanih vrst glede na njihov status.  
 Fig. 3: Share of the observed species in view of their status.



Sl. 5: Posamezni deleži potrjenih in verjetnih gnezdičk glede na njihov status ogroženosti.  
 Fig. 5: Separate shares of confirmed and probable breeders in view of their threat status.



## REZULTATI IN DISKUSIJA

## Winter residents (Z)

Približno 53% oziroma 78 vrst opazovanih ptic v dolini Reke prezimuje, večina le-teh pa je stalnic (Tab. 2, Sl. 3, 4). 16 vrst ptic se v dolini pojavlja le pozimi, in sicer: siva gos (*Anser anser*): 1-13 osebkov, sokolič (*Falco columbarius*): opazovan le en osebek, priba (*Vanellus vanellus*): 4-36 osebkov, pflaninska pevka (*Prunella collaris*): 1-2 osebkov, siva pevka (*P. modularis*): 2-10 osebkov, brinovka (*Turdus pilaris*): 1-2000 osebkov, mali krivokljun (*Loxia curvirostra*), veliki srakoper (*Lanius excubitor*): 5-10 osebkov, pinoža (*Fringilla montifringilla*), mali detel (*Dendrocopos minor*), kavka (*Corvus monedula*), mala uharica (*Asio otus*), mala cipa (*Anthus pratensis*), vriskarica (*A. spinoletta*), čizek (*Carduelis spinus*) ter brezovček (*C. flammea*): 3 do 20 osebkov. Z izjemo brinovke je velikost drugih populacij prezimujočih ptičjih vrst razmeroma skromna.

## Preletniki (P)

12% vseh opazovanih ptic v dolini zavzemajo preletniki (Tab. 2, Sl. 3, 4), in sicer: pikasti martinec (*Tringa ochropus*): 3-7 osebkov, rdečenoga postovka (*Falco vespertinus*): 2-9 osebkov, bičja (*Acrocephalus schoenobaenus*) in srpična trstnica (*A. scirpaceus*), rjavi lunj (*Circus aeruginosus*), bela štoklja (*Ciconia ciconia*): 1-3 osebkov, kobiličar (*Locustella naevia*), rumeni vrtnik (*Hippolais icterina*), belovrati muhar (*Ficedula hypoleuca*): 1-12 osebkov, kostanjek (*Aythya nyroca*): samica opazovana 18. 7. 1996, reglja (*Anas querquedula*): 3-7 osebkov, sivi žerjav (*Grus grus*), mala bela čaplja (*Egretta garzetta*): opazovani 3 osebkov, beloglavi jastreb (*Gyps fulvus*): 1-3 osebkov. Sršenar (*Pernis apivorus*) gnezdi nad dolino Reke, in sicer v predelu, ki ga območje teh raziskav ni zajelo. Dolino pa relativno pogosto preletava. Raziskave za zdaj kažejo, da dolina ni pomembno postajališče za preletnike, saj se tu med preletom pojavlja relativno majhno število vrst ptic (Tab. 1, Sl. 4), kar gre v veliki meri pripisati dejstvu, da tu ni obsežnejših vodnih površin in zamočvirjenih predelov oziroma polojev, kjer bi ptice, zlasti pobežniki, lahko stikale za hrano.

Opazovanje skalnega brgleza (*Sitta neumayer*) 22. 7. 1996 v kamnolomu nad Ilirsko Bistrico je prvo opazovanje te vrste v Sloveniji. Osebek je na dosegu roke (!) stikal med skalami za pajki. Po vsej verjetnosti je šlo za naključnega gosta.

## Gnezditke (Gn in Gn?)

Izmed 147 opazovanih vrst ptic jih na obravnavanem območju zagotovo gnezdi 85, 19 pa po vsej verjetnosti (Tab. 2, Sl. 3, 4). Dobra tretjina je na Rdečem

seznamu ogroženih vrst ptic v Sloveniji (Sl. 5). Puščavca (*Monticola solitarius*) sem označil kot verjetnega gnezditke, ker je bil opazovan v gnezditveno sumljivem času ter primernem habitatu. 1 osebek je bil opazovan 22. 7. 1996 v kamnolomu nad Ilirsko Bistrico. Ustrezen gnezditveni habitat kaže na širjenje gnezditvenega areala v Sloveniji te mediteranske vrste ptice (Polak, 1998). Sledi krajši opis vrst z Rdečega seznama ogroženih ptic gnezditk Slovenije:

**Rakar - *Acrocephalus arundinaceus***

Pop. max: 5 parov

Pop. min: 2 para

Ogroženost: E 2.c

Gnezditveni status: Gn

Rakar v času opazovanj redno poje na treh odsekih s trstičjem obrasle Reke. Predel med Dolnjim Zemonom in Ilirsko Bistrico, kjer je rakar pel, je zaradi melioracijskih posegov v strugo Reke uničen.

**Mali martinec - *Actitis hypoleucos***

Pop. max: 5 parov

Pop. min: 2 para

Ogroženost: E 2.c

Gnezditveni status: Gn

Gnezdi na zaraščenem obrežju Reke; št. gnezdečih parov se je v letih opazovanj zmanjšalo na 2 predvsem zaradi nadaljnjih posegov v strugo Reke.

**Vodomec - *Alcedo atthis***

Pop. max: 6 parov

Pop. min: 3 pari

Ogroženost: E 2.c

Gnezditveni status: Gn

Vodomec je reden gnezditke obrežij Reke, opazovati pa ga je moč tudi pozimi. V letu 1997 sta bili uničeni dve erodirani obrežni steni, ki sta ju nadomestili utrjeno kamenje in borovi piloti.

**Kotorna - *Alectoris graeca***

Pop. max: 10 parov

Pop. min: 5 parov

Ogroženost: E 2.b

Gnezditveni status: Gn

Kotorna prebiva na kraških goličavah nad Ilirsko Bistrico (Cure), kjer del travnikov ponazarja košenice, del pa pašnike za drobnico.

**Planinski orel - *Aquila chrysaetos***

Pop. max: 1 par

Pop. min:

Ogroženost: V 3.a

Gnezditveni status: Gn

Gnezdo planinskega orla nad zgornjim tokom Reke je eno od dveh ali treh gnezd širšega območja, ki ga po vsej verjetnosti izbira isti par. V letih 1997 in 1998 je

par gnezdil nad dolino, v letu 1999 pa nad Koritnicami. Gnezdeči par varuje dogovor z lokalnim jadrano-padalaskih društvom o prepovedi preletov gnezda v času gnezdenja.

#### Čuk - *Athene noctua*

Pop. max: 5 parov

Pop. min: 3 pari

Ogroženost: E 2.c

Gnezditveni status: Gn

Čuk je redni gnezdilec v dolini, za gnezda si v dolini izbira dupla, suhe zidne špranje in gnezdilnice.

#### Velika uharica - *Bubo bubo*

Pop. max: 2 para

Pop. min: 1 par

Ogroženost: E 2.c

Gnezditveni status: Gn

Velika uharica je do nedavnega gnezdila v ostenju Podtabra, pred nekaj leti pa je skrivnostno izginila; na isti polici gnezdi sokol selec.

#### Podhujka - *Caprimulgus europaeus*

Pop. max: 20 parov

Pop. min: 5 parov

Ogroženost: E 2.c

Gnezditveni status: Gn

Pogosta gnezdilka predvsem nad dolino Reke.

#### Mali deževnik - *Charadrius dubius*

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: V 3.c

Gnezditveni status: Gn

Malega deževnika ogrožajo, podobno kot malega martinca, hidromelioracijski posegi v strugo Reke. Gnezdi na majhnih prodiščih, ki jih na Reki ni veliko.

#### Povodni kos - *Cinclus cinclus*

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: V3.b

Gnezditveni status: Gn?

Povodni kos prebiva v dolini že dolgo časa, o čemer pričajo "trofeje" nagačenih osebkov pri starejših lovcih. Tako pozimi kot poleti je moč opazovati dva para na Reki, 1 osebek pa ob Bistrici v sami Ilirski Bistrici.

#### Skalni golob - *Columba livia*

Pop. max: 60

Pop. min: 2

Ogroženost: E 2.b

Gnezditveni status: Gn

Skalni golob gnezdi v manjših breznih nad dolino ter v ostenjih Podtabra. Pred nekaj leti še številna populacija sedaj močno upada. V letu 1999 sta tako gnezdila

le še dva para. Pregledovanje skubišč pa je še pokazalo, da je pomemben plen za sokola selca, ki gnezdi na isti lokaciji.

#### Prepelica - *Coturnix coturnix*

Pop. max: 20

Pop. min: 15

Ogroženost: V 3.c

Gnezditveni status: Gn

Prepelico najdemo v dolini na istih travnikih kot kosca, le da pri višini steblik travišča ni tako izbirčna. Številčnost gnezdilne populacije se bistveno ne spreminja.

#### Kosec - *Crex crex*

Pop. max: 62

Pop. min: 7

Ogroženost: E 2.c

Gnezditveni status: Gn

Kosec je globalno ogrožena vrsta ptice in v dolini poleg ostalih globalno ogroženih vrst najbolj prispeva k mednarodni ornitološki pomembnosti območja. V raziskavah v letih 1992-93 je bila ocenjena populacija od 20-30 pojočih samcev (Trontelj, 1995; 1996), velikost pop. pa se v naslednjih letih ni bistveno spreminjala. V letu 1999 smo po temeljitem kartiranju doline našli 64 pojočih samcev. Mozaičen preplet obdelovalnih površin in površin v zaraščanju ali kolo-barju oziroma neenoten režim zgodnje košnje in ekstenzivno kmetijstvo omogočajo koscu dovolj pestro izbiro habitatov. Pa vendar se v nekaterih predelih pojavlja problem zgodnje košnje.

#### Sokol selec - *Falco peregrinus*

Pop. max: 2 para

Pop. min: 1 par

Ogroženost: E 2.c

Gnezditveni status: Gn

V letih 1996-1997 je sokol selec gnezdil v ostenju Podtabra. Pregledovanje skubišč je pokazalo, da tu živi vse leto. Redno je bilo moč opazovati ptico na lovu tudi v zgornjem delu doline, kjer je dovolj primernih previsnih sten za gnezdenje.

#### Škrjančar - *Falco subbuteo*

Pop. max: 2 para

Pop. min: 1 par

Ogroženost: V 3.c

Gnezditveni status: Gn?

Ptica je bila opazovana na celotnem območju, redno pa ob manjši mlaki, kjer se je podila za kačjimi pastirji. Opazovana je bila tudi na lovu za poljskimi škrjanci in kmečkimi lastovkami na isti lokaciji. V dolini po vsej verjetnosti gnezdi.

**Navadna postovka - *Falco tinnunculus***

Pop. max: 2 para

Pop. min: 1 par

Ogroženost: V 3.c

Gnezditveni status: Gn

Največ navadnih postovk dolino preleti, vendar v njej redno gnezditva vsaj dva para, eden v gnezditnici.

**Kozica - *Gallinago gallinago***

Pop. max: 3 pari

Pop. min: 2 para

Ogroženost: E 2.a

Gnezditveni status: Gn?

V dolini se redno pojavlja na preletu. Junija 1996 in konec maja 1997 pa je bilo pod Zarečico opazovanih 4 oziroma 6 osebkov, od katerih sta se v letu 1996 2, v letu 1997 pa 3 območno spreletavali. Kasneje gnezdo ni bilo najdeno.

**Mala bobnarica - *Ixobrychus minutus***

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: E 2.a

Gnezditveni status: Gn?

Par male bobnarice sem od 4.5. do 26.5. 1996 opazoval ob mrtvici, zaraščeni z vrbovjem in trstičjem, pri Zarečici. 16. 6. 1997 je bil na lovu opazovan 1 osebek pri Kosezah, 23. 6. 1997 pa pri Zarečici. V maju 1999 sem posamezne osebeke spet opazoval v trstičju pri Kosezah. Spričo ugodnih gnezditvenih habitatov na opazovanih lokacijah uvrščam ptico med verjetne gnezditke.

**Vijglavka - *Jynx torquilla***

Pop. max: 10 parov

Pop. min: 5 parov

Ogroženost: V 3.c

Gnezditveni status: Gn

Vijglavka gnezdi v duplu, ki jih največ najde v visokostebelnih senoženjnih sadovnjakih. Kljub temu, da je starih sadovnjakov v dolini še precej, zaseda tudi gnezditnice. Je relativno pogosta gnezditka doline.

**Črnočeli srakoper - *Lanius minor***

Pop. max: 1 par

Pop. min:

Ogroženost: E 1.2.c

Gnezditveni status: Gn

Črnočeli srakoper je leta 1995 gnezdil pri Jablanici (Polak, 1997). Gnezdo je bilo zneseno na koncu jablanove veje. Toda tako izpostavljeno gnezdo so kasneje izropale srake.

**Čebelar - *Merops apiaster***

Pop. max: 1 par

Pop. min:

Ogroženost: E 1.2.a

Gnezditveni status: Gn

Leta 1996 je v erodiranem bregu Reke pod Kosezami uspešno gnezdil 1 par, izpeljalo se je 6 mladičev. V naslednjem letu je bil poleg starega opažen izkopan nov rov, vendar ptici kasneje nista gnezdili. Ogrožajo ga melioracijski posegi v strugo Reke oziroma regulacije Reke, ki se bodo, kot kaže, nadaljevale in uničile edino gnezditveno lokaliteto čebelarja na Primorskem.

**Veliki strnad - *Miliaria calandra***

Pop. max: 50 parov

Pop. min: 30 parov

Ogroženost: V 3.c

Gnezditveni status: Gn

Poleg rjavega srakoperja najpogostejša gnezditka doline z veliko gnezditveno gostoto. V letu 1999 sem v zgornjem delu obravnavanega predela z metodo linijskega transeka ugotavljal gostoto pojočih samcev in prišel do številke 9-11 / km<sup>2</sup>.

**Slegur - *Monticola saxatilis***

Pop. max: 17

Pop. min: 10

Ogroženost: V 3.b

Gnezditveni status: Gn

Slegurji prično peti na Gurah nad dolino okrog 1. maja, kjer sem med Milanjem in Goljakom naštel 14 pojočih samcev. Po en par gnezdi tudi v treh kamnolomih nad dolino Reke.

**Kvakač - *Nyctycorax nyctycorax***

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: E 1.2.a

Gnezditveni status: Gn?

4. 5. 1997 sem v mrtvici, zaraščeni z rogozom in vrbovjem, opazoval 3 odrasle osebeke. 6. junija istega leta pa en odrasel in en mladosten osebek, ki sta se na omenjeni lokaciji zadrževala še nekaj dni. 25. 5. 1998 sem opazoval kvakača ob Reki pri Zarečju, 4. 6. pa ob Reki pri Kosezah. 20. 5. 1999 se je v mraku v trstičju pod Kosezami kvakač značilno oglašal, 27. 5. pa sem ob Reki pri Kosezah s tal dvignil mladostni osebek, ki je komaj poletel. Istega dne sem opazil odraslega kvakača pod Zarečico. V letu 1999 sem med nočnimi popisi koscev pri mrtvici pod Zarečico ujel tudi značilno kvakačevo oglašanje. Njegov gnezditveni habitat ogroža urejanje struge Reke ter odstranjevanje obrežne vegetacije.

**Veliki skovik - *Otus scops***

Pop. max: 10 parov

Pop. min: 6 parov

Ogroženost: E 2.c

Gnezditveni status: Gn

V dolini se prične veliki skovik oglašati v sredini aprila. Je najpogostejša sova, ki gnezdi v dolini. V Ilirski Bistrici gnezdi 3-4 pari.

**Siva žolna - *Picus canus***

Pop. max: 10

Pop. min: 5

Ogroženost: V 3.c

Gnezditveni status: Gn

Tako v dolini kot tudi v sosednjih Brkinih pogosta vrsta žolne. V višjih predelih nad dolino jo nadomešča zelena žolna.

**Zelena žolna - *Picus viridis***

Pop. max: 10

Pop. min: 5

Ogroženost: V 3.c

Gnezditveni status: Gn

Zelena žolna je bila v dolini opazovana samo enkrat, pač pa je pogostejša na košenicah nad dolino Reke.

**Grahasta tukalica - *Porzana porzana***

Pop. max: 5 parov

Pop. min: 3 pari

Ogroženost: E 2.a

Gnezditveni status: Gn?

17. 4. 1997 sem opazoval grahasto tukalico v šasju ob mrtvici pri Zarečici. 28. 5. naslednjega leta sem na isti lokaciji podnevi opazoval 2 osebk, med nočnimi popisi koscev istega leta pa sem v ostrem šasju in trstičju med Kosezami in Dolnjim Zemonom slišal klice 2-3 samcev.

**Mokož - *Rallus aquaticus***

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: E 2.c

Gnezditveni status: Gn?

Značilno knuljenje mokoža je bilo slišati trikrat, in sicer: 10. 5. 1997 v rogozju pod Zarečico in vrbovju pri tovarni Lesonit (Polak, *ustno*) ter 28. 5. 1999 v trstičju med Kosezami in Dolnjim Zemonom.

**Plašica - *Remiz pendulinus***

Pop. max: 3 pari

Pop. min: 1 par

Ogroženost: V 3.b

Gnezditveni status: Gn?

15. 6. 1997 sem opazoval pojočega samca pri Vrbovem, 18. 7. istega leta pa ob Reki nedaleč od prve

lokacije. Plašico sem opazoval še 22. 6. 1998, vendar tako v letih 1997 kot 1998 značilnega gnezda nisem našel.

**Repaljščica - *Saxicola rubetra***

Pop. max: 20 parov

Pop. min: 10 parov

Ogroženost: E 2.c

Gnezditveni status: Gn

Repaljščica je relativno pogosta vrsta ptice, ki gnezdi po celotni dolini, če je le dovolj visoke trave oziroma suhih stebel kobulnic, od koder opreza za žuželkami.

**Siva penica - *Sylvia communis***

Pop. max: 30 parov

Pop. min: 20 parov

Ogroženost: V 3.c

Gnezditveni status: Gn

Poleg črnoglavke najpogostejša vrsta penice. Gnezdo si ob Reki spleta tudi iz orjaške rozge (*Solidago gigantea*).

**Grahasta penica - *Sylvia nisoria***

Pop. max: 15

Pop. min: 5

Ogroženost: V 3.b

Gnezditveni status: Gn

Grahasto penico sem opazoval v dolini kot tudi na pobočjih nad dolino Reke, kjer je bolj pogosta, gnezdo pa si najpogosteje spleta v rešeljiki (*Prunus mahaleb*) in črnem trmu (*Prunus spinosa*).

**Pegasta sova - *Tyto alba***

Pop. max: 2 para

Pop. min: 1 par

Ogroženost: E 2.c

Gnezditveni status: Gn

Pegasta sova je v letu 1996 gnezdila v duplu bele vrbe (*Salix alba*) pri Kosezah (Milavec, *ustno*). V letu 1999 pa se je en osebek značilno oglašal iz zapuščene šole v Kuteževem.

**Smrdokavra - *Upopa epops***

Pop. max: 20 parov

Pop. min: 10 parov

Ogroženost: E 2.c

Gnezditveni status: Gn

Smrdokavro sem opazoval v dolini Reke, pogostejša pa je nad dolino, kjer se v gozdovih puhavca, malega jesena in črnega gabra ter med nasadi črnega bora značilno oglašja, hrano pa si išče tudi po iztrebkih drobnice na košenicah. Gnezdo je bilo najdeno v kamniti zidni terasi zapuščenega vinograda. Po pripovedovanju domačinov je bila ta ptica v preteklosti mnogo pogostejša.

### Ogroženost območja

Zaradi stika med kraškim in nekraškim svetom ima porečje Reke posebne pokrajinske vrednote, ki pa se zaradi človeških posegov izgubljajo. Zaradi z lesom bogatega zaledja Snežnika in vodnatosti doline se je na žagarski tradiciji razvila lesna industrija, ki je še danes glavni vir degradacije pokrajine zlasti v smislu posegov v samo Reko. Najbolj usodno je seveda onesnaževanje Reke, kjer je leta 1987 več kot polovica celotnega toka Reke uvrščena v III.-IV. kakovostni razred (Rojšek, 1987). Leto poprej (1986) so bile Škocjanske jame vpisane na UNESCOV seznam naravne in kulturne dediščine!

Samočistilni procesi Reke so zelo upočasnjeni zaradi še vedno močno onesnaženih bregov kot tudi zaradi divjih odlagališč, prav tako oči in nos pa bode še vedno nesanirano odlagališče stranskih produktov proizvodnje Tovarne organskih kislin pri Globovniku. Meteorne vode se iz omenjenega odlagališča stekajo seveda v Reko.

Večina Reke od izvira do ponora je danes med drugim in tretjim kakovostnim razredom, kar pa se spreminja glede na pretok in oddaljenost od virov onesnaževanja zaradi povečanih samočistilnih procesov. Razredčevanje odplak v Reki z vodo iz akumulacij Klivnik in Moša seveda ni pravi in tudi ne zadovoljiv način čiščenja Reke. Le učinkovita komunalna čistilna naprava, ki bi čistila komunalne odplake Ilirske Bistrice in vasi po dolini, ter nadzor proizvodnje oziroma manipulacije odpadnih vod omenjenih onesnaževalcev bi zagotavljala obstoj Reke v drugem kakovostnem razredu.

Izkoriščanje zemljišč v bližnji okolici Reke je omejeno skoraj izključno na košnje travnikov, kajti ti so v kmetijskem smislu kakorkoli drugače slabše donosni. Ravno usklajevanje termina košnje vlažnih travnikov z gnezdenjem ptic bi bilo za gnezdilke tovrstnih habitatov velikega pomena, ker se čas košnje velikokrat časovno ujema z gnezdenjem. Veliko vlažnih oziroma močvirskih travnikov, zlasti tistih neposredno ob Reki, je v fazi zaraščanja. Ker se košnja trave (in kasnejše spravilo sena) cenovno ne izplača, veliko kmetov na pol posušeno travo na polju kar zažge. Dogaja se tudi, da s pokošeno travo stresajo v manjše mlake in mrtvice Reke, gnezdilne habitate redkih in ogroženih vrst ptic, s čimer nepotrebno prispevajo k evtrofikaciji vode in neposrednemu uničevanju gnezdilnega habitata. Takšni habitati so tu problematični tudi zaradi obstoja divjih odlagališč.

Da bi lastniki zemljišč pridobili večje kmetijske površine, določene predele trstičja, zlasti v zgornjem delu doline ter med vasema Zgornji in Dolnji Zemon, občasno požgejo. Ti tudi za ornitofavno tako pomembni habitati so v dolini precej redki in se z izjemo nekoliko obsežnejšega in strnjenelega predela med omenjenima vasema ter med Dolnjim Zemonom in Kosezami pojavljajo bolj fragmentarno. Del s trstičjem obraslega obrežja Reke, kjer je leta 1997 pel rakar, pa je zaradi melioracijskih posegov v strugo Reke spremenjen v utrjen nasip.

Divjo naravo Reke že dalj časa skušajo krotiti z različni posegi v strugo za preprečevanje vsakoletnih poplav. Obsežnejša hidromelioracijska dela so bila že opravljena na strugi oziroma bregovih med Zabičami in Trpčanami, kjer so že odstranili obrežno vegetacijo in prodnate nanose, utrdili obrežje oziroma ga obložili s kamenjem različne velikosti, izravnali meandre in jih utrdili z borovimi piloti. Tako so uničili manjša prodišča, ki jih ob Reki ni ravno veliko, in naravne rečne bregove, zlasti tiste, ki jih Reka izpodjeda in tako ustvarja ugodne gnezdilne habitate za številne vrste divjih čebel, vodomca in čebelarja. Odstranjevanje obrežne vegetacije, ki spremeni značilno podobo pokrajine, pa poleg dejstva, da se s tem drastično spremenijo okoljski dejavniki v reki in s tem življenjske razmere v reki, še povečuje erozijsko moč Reke. Tako so uničena tudi prodnata in s kisikom dobro prezračena obrežja, ki jih ribe navadno izbirajo za odlaganje iker. Urejanja v smislu ustvarjanja umetnih rečnih pragov (po strugi navzdol vse do Ilirske Bistrice), z namenom prezračevanja reke, pa onemogočajo migracijo živali po toku navzgor. Podobni melioracijski posegi so bili opravljeni še v predelu Samsovega mlina, med mostom na Žabovici in železniškim mostom Ilirska Bistrica - Rijeka. Tudi tu je večinoma odstranjena obrežna vegetacija, bregovi pa utrjeni s kamenjem. Predvideno je nadaljnje urejanje struge Reke od Ilirske Bistrice navzdol v smislu omejevanja vsakoletnega poplavljanja zlasti zaradi tovarne Lesonit, ki ne neha krojiti usode Reke, in pa graditve komunalne čistilne naprave v bližini vasi Topolc. Zanimivo je, da kljub dosedanjim posegom v strugo Reke le-ta redno, vsakoletno prestopa bregove.

### ZAHVALA

Zahvaljujem se Slavku Polaku za prijetne skupne ure terenskega dela ter za kritičen pregled članka.

## ORNITHOFAUNA OF THE UPPER REKA VALLEY AND ITS NEIGHBOURHOOD

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## ABSTRACT

During 1994-1999, 147 bird species were observed in the Reka valley and its neighbourhood, 85 of which were confirmed breeders, 19 possible breeders and 25 passage migrants; 78 were winter residents. An increase in the population of Corn Crake *Crex crex* was noted, as well as rather large breeding density of Red-backed Shrike *Lanius collurio* and Corn Bunting *Miliaria calandra*. The banks of the Reka river represent the only breeding habitat of the European Bee-eater *Merops apiaster* in SW Slovenia. In the stone-pit above Ilirska Bistrica, a Western Rock Nuthatch *Sitta neumayer* was observed - the very first observation of this species in Slovenia. The breeding habitats immediately along the river and reed-beds have been greatly endangered by land drainage.

**Key words:** ornithology, the Reka valley, Primorska region, SW Slovenia

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## NETOPIRJI NA PREZIMOVALIŠČIH V SLOVENIJI V LETIH 1994-1996

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## IZVLEČEK

Med letoma 1994 in 1997 smo obiskali 40 jam in v njih beležili prisotnost prezimujočih netopirjev. V 30 jamah smo našli osem vrst: *Rhinolophus ferrumequinum*, *R. hipposideros*, *R. euryale*, *Myotis myotis*, *M. daubentoni*, *Eptesicus serotinus*, *Barbastella barbastellus* in *Miniopterus schreibersi*. V isti jami smo našli do štiri vrste, vendar sta bila v večini prezimovališč (83,3%) ena ali dve vrsti. Populacijsko gostoto *R. ferrumequinum* na Dolenjskem smo ocenili na približno 0,3 netopirja/km<sup>2</sup>.

**Ključne besede:** Chiroptera, hibernacija, jame, inventarizacija, Slovenija

## UVOD

Že ob koncu 80-ih let, ko je bila končana prva inventarizacija sesalcev Slovenije (Kryštufek, 1991), je bil očiten relativno slab nivo poznavanja netopirjev. Da ublažimo to pomanjkljivost, smo v 90-ih letih opravili nekaj terenskih raziskav, ki so dale več, za netopirsko favno Slovenije novih in zanimivih podatkov (Kryštufek & Červený, 1997). Ker smo ocenili, da so vsi v Sloveniji živeči netopirji pomembni tudi z naravovarstvenega stališča (Kryštufek, 1996), smo bili posebej pozorni na njihova prezimovališča v podzemskih jamah. O tej tematiki sta doslej pisala Djulic (1959) in Frank (1970, 1983). V članku predstavljamo podatke, zbrane v letih 1994-1996. Zaradi pomanjkanja časa, sredstev in usposobljenega osebja je pregled vse prej kot popoln. Ne glede na to je doslej najbolj temeljit in časovno zgoščen popis. Podatki, ki smo jih zbrali, so danes že del zgodovine, zato verjameva, da bodo na tej osnovi zanamci laže in zanesljiveje sklepali o morebitnih populacijskih trendih troglofilnih vrst netopirjev.

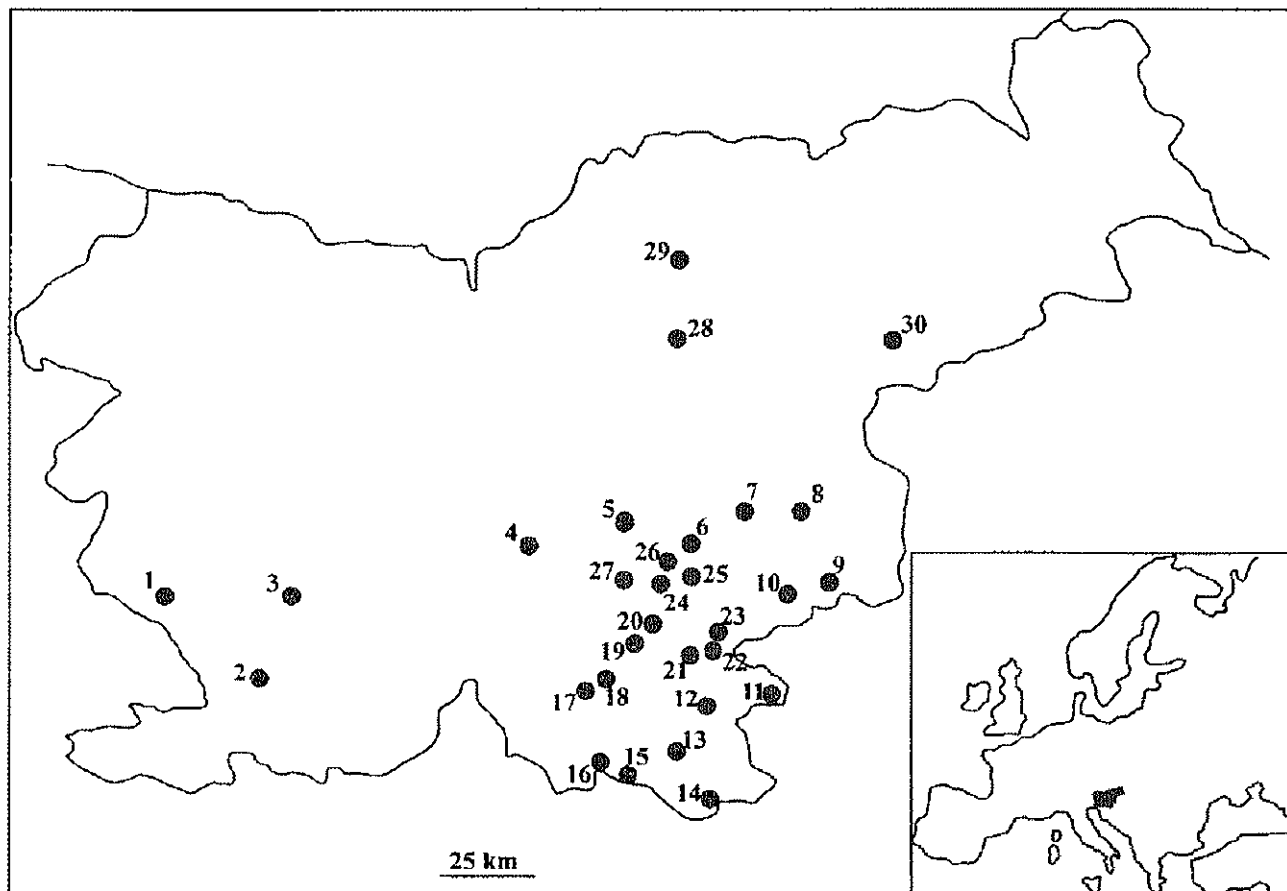
## MATERIAL IN METODE

Popisovali smo v jamah Dolenjske, Bele krajine, Primorske, Notranjske in Štajerske. Popise smo opravili v letih 1994-1996, vselej med 15. januarjem in 13. marcem. Obiskovali smo jame, za katere so bili netopirji že navedeni, ali pa smo zanje domnevali, do so potencialno prezimovališče netopirjev. Netopirje smo iskali ob pomoči svetilk. V primeru razpršenih kolonij smo živali neposredno preštevali, zgoščene kolonije pa smo fotografirali in netopirje prešteli na projekciji posnetka. Pokazalo se je, da z neposrednim preštevanjem lahko močno precenimo število osebkov v zgoščeni koloniji, tako da je ocenjevanje s fotografije veliko zanesljivejše.

## REZULTATI

## Pregledane jame

Opravili smo 46 obiskov v 40 jamah, prisotnost netopirjev pa je bila potrjena v 30 jamah (75%). Največ jam smo pregledali na Dolenjskem in v Beli krajini (33), sledijo pa Štajerska (4 jame), Primorska (2 jami) in Notranjska (ena jama).



Sl. 1: Zemljevid Slovenije s podzemskimi objekti, v katerih smo v letih 1994-96 našli netopirjev v hibernaciji. Za identifikacijske številke glej besedilo.

Fig. 1: Map of Slovenia showing caves with hibernating bats found between 1994 and 1996. See text for registration numbers.

**Tolmač k podajanju rezultatov:**

- Zaporedne številke, pod katerimi so jame navedene v poglavju "Rezultati", ostrezajo identifikacijskim številkam na sliki 1.
- Katastrska številka inventarja Jamarske zveze Slovenije (v oklepaju).
- Datum: dan, mesec, leto.
- Okrajšave rodovnih imen: *R.* - *Rhinolophus*, *M.* - *Myotis*, *E.* - *Eptesicus*, *B.* - *Barbastella*, *Mi.* - *Miniopterus*.
- Številka (v oklepaju) za imenom vrste pomeni število prešteti živali.

**Jame z netopirji v hibernaciji  
(Caves with hibernating bats)**

**Primorska**

1. Jama v doktorjevi ogradi (948)

31.01.1996: *R. hipposideros* (1), *R. ferrumequinum* (1).

2. Škocjanske jame (735)

31.01.1996: *Mi. schreibersi* (1).

09.03.1996: *Mi. schreibersi* (18).

**Notranjska**

3. Predjama (734)

31.01.1996: *R. hipposideros* (9), *R. ferrumequinum* (150), *M. daubentoni* (1), *Mi. schreibersi* (250).

**Dolenjska in Bela krajina**

4. Krška jama (74)

01.02.1994: *R. hipposideros* (17), *R. ferrumequinum* (5), *M. myotis* (1).

28.02.1996: *R. hipposideros* (9), *R. ferrumequinum* (1).

5. Velika jama nad Trebnjem (104)

01.02.1994: *R. hipposideros* (5), *B. barbastellus* (1).

6. Ajdovka, Šentjurij (2116)  
05.03.1996: *R. hipposideros* (10).
7. Zgornja Klevevska jama (411)  
01.02.1994: *R. hipposideros* (3), *R. ferrumequinum* (1),  
*M. myotis* (1).
8. Ajdovska jama pri Nemški vasi (417)  
01.02.1994: *R. hipposideros* (1).
9. Levakova jama (517)  
02.02.1995: *R. hipposideros* (1), *M. daubentoni* (1).
10. Kostanjeviška jama (518)  
01.02.1994: *R. hipposideros* (10), *R. ferrumequinum*  
(58), *R. euryale* (150).  
13.03.1994: *R. ferrumequinum* (60).
11. Vidovec (3342)  
03.02.1994: *R. hipposideros* (1).
12. Malikovec (2613)  
03.02.1994: *R. ferrumequinum* (1).
13. Kaščica (2852)  
27.02.1994: *R. hipposideros* (3), *R. ferrumequinum* (11).
14. Jama v kamnolomu (2950)  
03.02.1994: *R. hipposideros* (1).
15. Spodnja Bilpa (630)  
03.02.1994: *R. hipposideros* (1).
16. Velika Kobilna jama (144)  
03.02.1994: *R. hipposideros* (1).
17. Ajdovska jama na Radohi (6165)  
01.02.1994: *R. hipposideros* (1), *B. barbastellus* (2).
18. Jama pod Štalami (4003)  
31.01.1994: *R. hipposideros* (9), *R. ferrumequinum* (4).
19. Ahnenloch (573)  
08.02.1994: *R. hipposideros* (3).
20. Jazbina (114)  
01.02.1994: *R. hipposideros* (11), *R. ferrumequinum*  
(147).  
08.03.1994: *R. hipposideros* (5), *R. ferrumequinum*  
(147).  
29.02.1996: *R. hipposideros* (10), *R. ferrumequinum*  
(150).
21. Radoska jama (1357)  
01.02.1994: *R. hipposideros* (6), *R. ferrumequinum* (2).
22. Jama pod Macesnovo gorico (6156)  
31.01.1994: *B. barbastellus* (1).
23. Krojačevka (5597)  
15.01.1994: *R. hipposideros* (3), *R. ferrumequinum* (3).
24. Velika prepadna (425)  
01.02.1994: *R. hipposideros* (31), *R. ferrumequinum*  
(46).
25. Luknja (575)  
01.02.1994: *R. hipposideros* (7), *R. ferrumequinum* (14).  
08.03.1994: *R. hipposideros* (3), *R. ferrumequinum* (16).  
25.02.1996: *R. euryale* (1).
26. Slugova jama (1030)  
01.02.1994: *R. hipposideros* (9), *R. ferrumequinum* (46).
27. Jama nad izvrom Šice (112)  
03.02.1994: *E. serotinus* (1).
- Štajerska**
28. Pekel (553)  
01.02.1996: *R. hipposideros* (5).
29. Pilanca (520)  
01.02.1996: *R. hipposideros* (1).
30. Belojača (2204)  
01.02.1996: *R. hipposideros* (2), *R. ferrumequinum* (18).
- Jame brez netopirjev  
(Caves with no hibernating bats)**
- Dolenjska in Bela krajina**
- Rivčja jama (110)  
01.02.1994
- Mala jama nad Trebnjem (394)  
01.02.1994
- Bizjakova jama (brez katastrske številke; no identi-  
fication number)  
01.02.1994
- Spodnja Klevevska jama (410)  
01.02.1994
- Kobiljača (1281)  
03.02.1994
- Veliki Zjot, Sečje selo (1270)  
03.02.1994

Mali Zjot, Sečje selo (1818)  
03.02.1994

Dolenjski zdenec (1800)  
03.02.1996

Črničkova jama (111)  
03.02.1994

### Štajerska

Špehovka (509)  
01.02.1996.

### Pregled vrst

V jamah smo zabeležili 8 vrst, ki pripadajo obema pri nas živečima družinama (Rhinolophidae, Vespertilionidae). V isti jami smo našli do 4 različne vrste. V večini jam (83,3%) sta bili prisotni 1 ali 2 vrsti. Štiri vrste smo našli v eni sami jami (Predjama) (Tab. 1).

**Tab. 1: Število vrst prezimujočih netopirjev v posameznih jamah.**

**Tab. 1: Number of hibernating bat species per cave.**

| Število vrst/jamo<br>No. species in a cave | Število jam<br>No. of caves | %    |
|--|-----------------------------|------|
| 1  | 13                          | 43.3 |
| 2  | 12                          | 40.0 |
| 3  | 4                           | 13.3 |
| 4  | 1                           | 3.3  |

Število osebkov v posamezni jami je variiralo od ene do 410 (mediana = 6). V dobri polovici jam (66,3%) je bilo samo do 10 netopirjev (Tab. 2). Večje kolonije, ki so štele nad 100 netopirjev, smo zabeležili v treh jamah (10,0%): Kostanjeviška jama (218 netopirjev), Jazbina (160 netopirjev) in Predjama (410 netopirjev).

**Tab. 2: Število netopirjev na prezimovanju v jami.**

**Tab. 2: Number of hibernating bats per cave.**

| Število netopirjev/jamo<br>No. bats in a cave | Število jam<br>No. of caves | %    |
|---|-----------------------------|------|
| 1   | 9                           | 30.0 |
| 2 - 10  | 10                          | 33.3 |
| 11 - 50                                       | 6                           | 20.0 |
| 51 - 100                                      | 2                           | 6.7  |
| > 100   | 3                           | 10.0 |

Našteli smo 1089 netopirjev. Jame, v katerih smo opravili več obiskov, smo šteli samo enkrat, upoštevali pa smo največje število zabeleženih netopirjev. Kot je

razvidno iz tabele 3, pripada 99% vseh osebkov štirim izrazitim jamskim vrstam: trem podkovnjakom (*Rhinolophus*) in dolgokrilemu netopirju (*Miniopterus schreibersi*). Veliki podkovnjak (*Rhinolophus ferrumequinum*) je bil najpogostejši, sledil pa mu je dolgokrili netopir. Od pogostih štirih vrst, je bil mali podkovnjak (*Rhinolophus hipposideros*) najden v največjem številu jam, sledil pa mu je veliki podkovnjak (Tab. 3). Južni podkovnjak (*Rhinolophus euryale*) in dolgokrili netopir sta bila zabeležena vsak samo za po dve jami. Iz odnosa med številom zasedenih jam in številom preštetihi živali si lahko ustvarimo predstavo o socialnosti posameznih vrst. Rezultati kažejo, da je najbolj socialen dolgokrili netopir (268 osebkov v dveh jamah), sledijo pa mu južni podkovnjak (151 osebkov v dveh jamah), veliki podkovnjak (509 netopirjev v 15 jamah) in mali podkovnjak (152 netopirjev v 26 jamah). Klasifikacija ima lahko naravovarstveno aplikacijo, kajti bolj ko je vrsta socialna, bolj je ranljiva.

**Tab. 3: Povzetek cenzusa netopirjev na prezimovališčih v slovenskih jamah.**

**Tab. 3: Summary of bat census in hibernaculas in Slovenia.**

| Vrsta<br>Species        | Št. netopirjev<br>No. of bats | %     | Št. jam<br>No. of caves |
|-------------------------|-------------------------------|-------|-------------------------|
| <i>R. ferrumequinum</i> | 509                           | 46.7  | 15                      |
| <i>R. hipposideros</i>  | 152                           | 14.0  | 26                      |
| <i>R. euryale</i>       | 151                           | 13.9  | 2                       |
| <i>M. myotis</i>        | 2                             | 0.2   | 2                       |
| <i>M. daubentoni</i>    | 2                             | 0.2   | 2                       |
| <i>E. serotinus</i>     | 1                             | 0.1   | 1                       |
| <i>B. barbastellus</i>  | 4                             | 0.4   | 3                       |
| <i>M. schreibersi</i>   | 268                           | 24.5  | 2                       |
| Skupaj / Total          | 1089                          | 100.0 | 30                      |

### Komentarji k vrstam

Veliki podkovnjak *Rhinolophus ferrumequinum*

Veliki podkovnjak je izrazito jamski netopir, ki se pri mirovanju eksponira. Ker se v jamah pojavlja razmeroma pogosto, pri tem pa ga je tudi lahko opaziti, daje vtis pogoste vrste. Vseeno smo tekom našega cenzusa našli samo 509 velikih podkovnjakov. Pri tem je treba upoštevati, da smo preiskovali predvsem takšne jame, v katerih smo tega netopirja tudi pričakovali. Cenzus, ki smo ga opravili na Dolenjskem leta 1994 je bil zadosti zgoščen, da dopušča približno oceno populacije. S tem v zvezi je treba omeniti, da je vrsta stacionarna in, da ne migrira več kot 30 km (Hill & Smith, 1985). Ocenila sva, da smo pregledali približno tretjino jam, primernih za tega netopirja (vrsta nastopa predvsem v velikih podzemskih prostorih). V tem pri-



Sl. 2: Skupina velikih podkovnjakov *Rhinolophus ferrumequinum* na prezimovanju v Luknji. (Foto: A. Hudoklin).

Fig. 2: Group of greater horseshoe *Rhinolophus ferrumequinum* bats hibernating in the cave Luknja. (Photo: A. Hudoklin).

meru bi na Dolenjskem (površina približno 3500 km<sup>2</sup>) živel komaj kakih 1000 velikih podkovnjakov, kar pomeni gostoto 0,3 netopirja na km<sup>2</sup>. Če dopuščamo možnost, da smo število teh netopirjev v pregledanih jamah podcenili (npr. spregledali polovico živali, kar ni preveč verjetno), pridemo do številke 2000, kar je še zmeraj razmeroma malo.

Najpomembnejša prezimovališča velikega podkovnjaka v Sloveniji so:

1. Jazbina (150 osebkov)
2. Predjama (150 osebkov)
3. Kostanjeviška jama (58 osebkov)
4. Velika Prepadna (46 osebkov)
5. Slugova jama (46 osebkov)

Tab. 4: Število prezimujočih velikih podkovnjakov *Rhinolophus ferrumequinum* v jami.

Tab. 4: Number of hibernating greater horseshoe bats *Rhinolophus ferrumequinum* per cave.

| Št. netopirjev v jami<br>No. bats in a cave | Št. jam<br>No. caves | %    |
|---|----------------------|------|
| 1   | 3                    | 20,0 |
| 2 - 10                                      | 4                    | 26,7 |
| 11 - 50                                     | 5                    | 33,3 |
| 51 - 100                                    | 1                    | 6,7  |
| > 100                                       | 2                    | 13,3 |

V vzhodni Sloveniji je edino prezimovališče v Be-lojači, kjer pa smo našli vsega 18 velikih podkovnjakov. Vrsta se na prezimovanju redko pojavlja posamič. Najpogostejše so skupine, ki štejejo 11 do 50 netopirjev (Tab. 4, Sl. 2). Od skupnega števila (509

živali) je bila 392 velikih podkovnjakov (77% vseh prešteti velikih podkovnjakov) najdenih v vsega štirih jamah (13,3% pregledanih jam). Še drugače povedano, kar 300 podkovnjakov (58,9%) je bilo zgoščenih v samo dveh jamah (6,7%). Ti podatki jasno kažejo na potencialno ogroženost vrste.

#### Mali podkovnjak *Rhinolophus hipposideros*

Mali podkovnjak je veliko bolj razpršen od velikega. V večini jam je bil najden posamič ali v skupinah do 10 osebkov (Tab. 5). Zateka se tudi v manjše rove, kakršnih je na kraški podlagi veliko. Iz povedanega sledi, da ne moremo realno oceniti populacije te vrste. Večje skupine smo našli v vsega dveh jamah:

1. Krška jama (17 osebkov)
2. Velika Prepadna (31 osebkov)

Tab. 5: Število prezimujočih malih podkovnjakov *Rhinolophus hipposideros* v jami.

Tab. 5: Number of hibernating lesser horseshoe bats *Rhinolophus hipposideros* per cave.

| Št. netopirjev v jami<br>No. bats in a cave | Št. jam<br>No. caves | %    |
|---|----------------------|------|
| 1   | 9                    | 34,6 |
| 2 - 10                                      | 14                   | 53,9 |
| 11 - 50                                     | 3                    | 11,5 |

#### Južni podkovnjak *Rhinolophus euryale*

Najdba kolonije južnega podkovnjaka v Kostanjeviški jami je pomembna v več pogledih. Prvotno smo namreč domnevali (Kryštufek, 1991), da se v Sloveniji pojavljajo samo posamični osebki v dolini Kolpe in v submediteranskem območju. Kolonija v Kostanjeviški jami leži na samem robu areala vrste.

#### Navadni netopir *Myotis myotis*

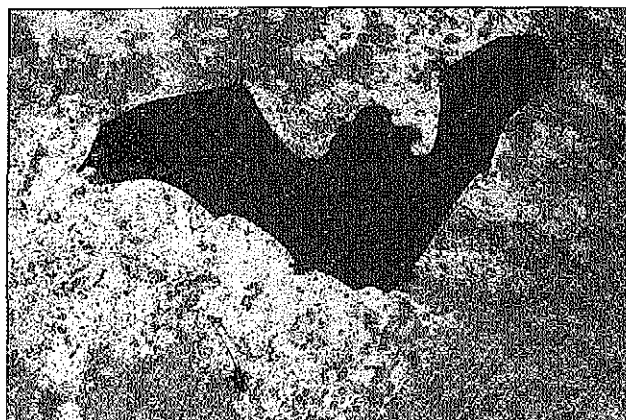
Zabeležili smo samo dva primerka v dveh jamah. O prezimovanju vrste v Sloveniji ne moremo z gotovostjo reči ničesar.

#### Obvodni netopir *Myotis daubertoni*

Vrsta je v Sloveniji pogosta, v jame pa se očitno zatekajo samo posamični osebki. Tega majhnega netopirja je tudi lahko spregledati, še posebej zato, ker hibernira posamič in v špranjah.

#### Pozni netopir *Eptesicus serotinus*

Našli smo en sam primerek (Sl. 3), kar pa seveda ni posledica redkosti vrste v Sloveniji.



Sl. 3: Med popisom v letih 1994-96 smo našli enega samega poznega netopirja *Eptesicus serotinus*. (Foto: A. Hudoklin).

Fig. 3: During our survey 1994-96 we found a single hibernating serotine *Eptesicus serotinu*. (Photo: A. Hudoklin).

#### Širokouhi netopir *Barbastella barbastellus*

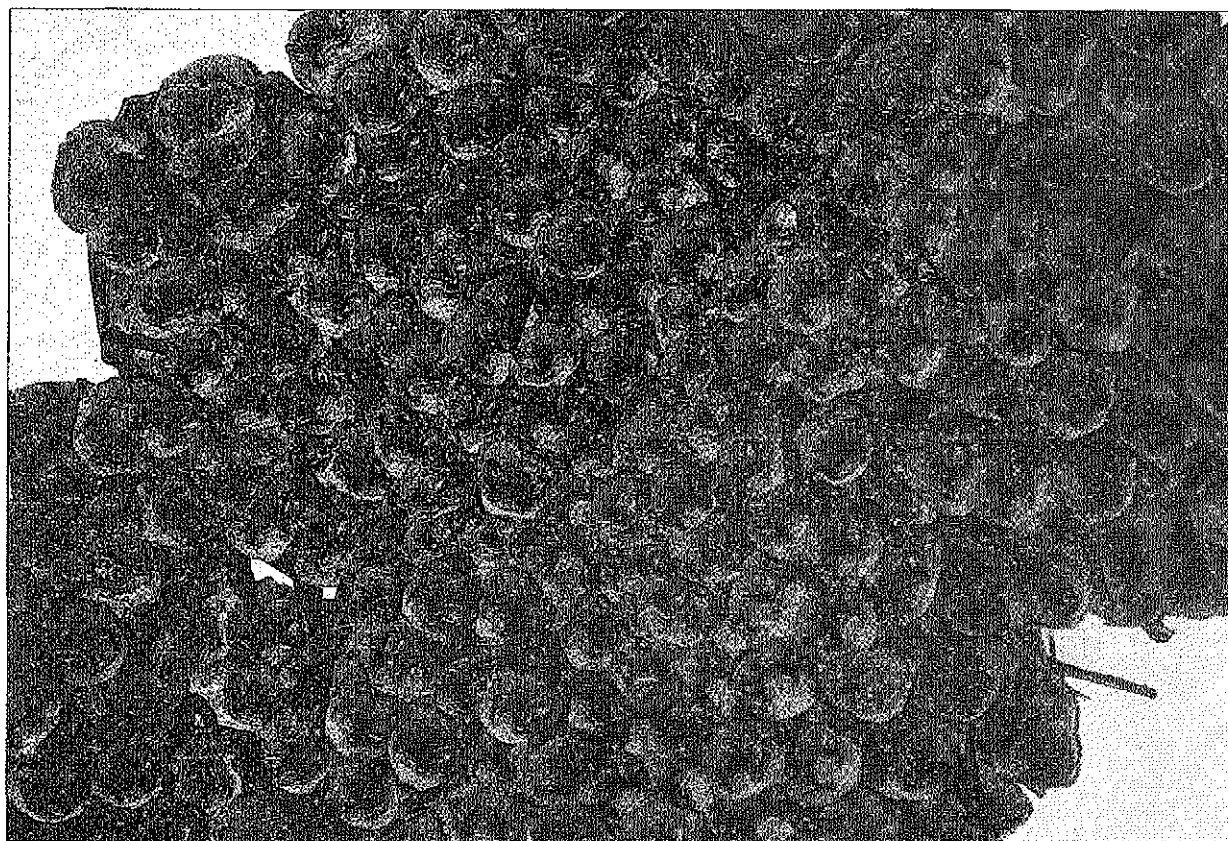
V jame se zateka samo ob najhujšem mrazu. Maloštevilni osebki, ki smo jih našli ob opravljanju cenzusa (vsega 4), ne odsevajo redkosti vrste v Sloveniji.

#### Dolgokrili netopir *Miniopterus schreibersi*

Prisotnost vrste smo potrdili v Predjami in v Škocjanskih jamah. Frank (1970), ki je domneval, da oba sistema poseljuje ista kolonija, je ocenil število živali na 1000. Po naši cenitvi šteje predjamska kolonija vsega 250 osebkov. Ker ocena temelji na štetju živali s posnetka (Sl. 4), se nam zdi dokaj zanesljiva.

#### ZAHVALA

Hvaležna sva vsem, ki so sodelovali pri terenskem delu. To so bili (abc): Vladimir Hanzal, Franc Janžekovič, Slavko Polak, Marcel Uhrin in Jan Zukan. Huw I. Griffiths je popravil angleški povzetek, Tihomir Makovec pa je izdelal sl. 1.



Sl. 4: Skupina dolgokrilih netopirjev *Miniopterus schreibersi* v Predjami. Število osebkov smo preštevali s takšnih posnetkov. (Foto: A. Hudoklin).

Fig. 4: Cluster of Schreiber's bats *Miniopterus schreibersi* in the Predjama cave. Bats were counted from such photographs. (Photo: A. Hudoklin).

## BATS IN HIBERNACULAS OF SLOVENIA 1994-1996

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## SUMMARY

We report results of a survey of bats hibernating in the caves of Slovenia. The survey was conducted between 1994 and 1996. Potential hibernaculas were visited between January 15 and March 13. Results are based on 46 visits to 40 caves. Presence of bats was confirmed in 30 caves (i.e. 75%). Of different regions of Slovenia, Dolenjska with Bela krajina were surveyed most thoroughly (33 caves), while only single caves were visited in Štajerska (4 caves), Primorska (2 caves), and Notranjska (a single cave). Results are summarised as follows:

- Identification number of the cave corresponds to the number on Figure 1.
- Name of the cave (note that "jama" is Slovene for a cave; "jame" in plural).
- Registration number of the cave, derived from the files of the Speleological association of Slovenia (in parentheses).
- Date: day, month, year (e.g. 31.01.1994 should be read as 31<sup>st</sup> of January 1994).
- Generic names are abbreviated as follows: R. - Rhinolophus, M. - Myotis, E. - Eptesicus, B. - Barbastella, Mi. - Miniopterus.
- Number of bats is given in parentheses following the name of the species.

In total we recorded eight species, but only up to four were found in a single cave. Majority of hibernaculas (i.e. 83.3%) contained merely one or two species, while four species were recorded in a single cave (Predjama; see Tab. 1).

Number of bats per cave varied between one and 410 (median was 6). More than half of the caves (i.e. 66.3%) contained up to ten bats (Tab. 2). Groups of more than 100 bats we found in merely three caves (i.e. 10%): Kostanjeviška jama (218 bats), Jazbina (160 bats), and Predjama (410 bats).

In total, we counted 1089 bats. Caves with several visits done, were counted only once and the highest number of bats was considered. Great majority of bats (i.e. 99%) belonged to four characteristic cave dwelling species: three horseshoe bats and a Schreibers' bat. The most common was the greater horseshoe bat (*R. ferrumequinum*), followed by the Schreibers' bat (*Miniopterus schreibersi*). Of the four species, the lesser horseshoe bat (*R. hipposideros*) was found in the largest number of caves, being followed by the Greater horseshoe bat (*R. ferrumequinum*; Tab. 3). On the base of our results, Schreibers' bat appeared to be the most social (268 specimens in two caves), followed by the Mediterranean horseshoe bat (151 specimens in two caves), greater horseshoe bat (509 bats in 15 caves) and the lesser horseshoe bat (152 bats in 26 caves).

Density of hibernaculas surveyed in Dolenjska with Bela krajina allowed us to estimate the total greater horseshoe bat population in that area. Assuming that approximately one third of caves, suitable for this species were visited, gives a crude estimate of 1000 greater horseshoe bats for the area of approximately 3500 km<sup>2</sup>, i.e. 0.3 bats per km<sup>2</sup>. Majority of groups had between 11 and 50 greater horseshoe bats (Tab. 4). Of the total number of 509 greater horseshoe bats, as counted, 300 (i.e. 58.9%) were in merely two caves (i.e. 6.7% of caves surveyed).

Lesser horseshoe bat was more dispersed if compared with his greater congeneric. In majority of hibernaculas, it was observed individually or in groups of up to ten specimens (Tab. 5). Other bats, with the exception of the Mediterranean horseshoe bat and Schreibers' bat, were observed in hibernaculas only exceptionally.

**Key words:** Chiroptera, hibernation, caves, survey, Slovenia



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## LETNA DINAMIKA POJAVLJANJA PODKOVNJAKOV (*Rhinolophus* spp.) V NEKATERIH JAMAH NA DOLENJSKEM

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### IZVLEČEK

Leta 1994 smo ugotavljali značilnosti letne dinamike pojavljanja populacij netopirjev iz družine podkovnjakov v njihovih najpomembnejših jamskih zatočiščih na Dolenjskem. V jamah Jazbina, Lukenjska in Krška jama so se prek celega leta zadrževali osebki vrste *Rhinolophus ferrumequinum* in *R. hipposideros*, v turistično urejeni Kostanjeviški jami pa tudi vrste *R. euryale*.

Pri opazovanih vrstah je bila v teku leta zabeležena podobna dinamika pojavljanja. Največ netopirjev je bilo v jamah v času hibernacije od novembra do začetka marca, potem pa se je do junija število postopno zmanjševalo. Junija smo v vhodnem delu Luknje in Jazbine opazovali tudi porodniške kolonije velikih podkovnjakov. Najmanj podkovnjakov smo zabeležili v jamah julija in avgusta, ko jih ob pregledih praktično ni bilo več. Lov z mrežo je vendarle potrdil pojavljanje manjšega števila osebkov, a tudi pogoste obiske netopirjev od zunaj. Septembra so se podkovnjaki začeli postopno zbirati v jamah, oktobra pa so bile kolonije že polnoštevilne. Dobljene podatke smo uporabili kot izhodišča za pripravo naravovarstvenih smernic pri upravljanju in varstvu jam.

**Ključne besede:** podkovnjaki, *Rhinolophus*, Chiroptera, letna dinamika, Dolenjska

### UVOD

Netopirji so ena najslabše preučevanih in tudi najbolj ogroženih skupin sesalcev v Sloveniji (Kryštufek 1991), vendar prav na tem prostoru dosegajo tudi veliko vrstno pestrost (Kryštufek & Červeny, 1997). Z izjemo prispevkov o njihovi razširjenosti so ekološko obarvani vpogledi v njihovo življenje redki. S tem člankom želimo prispevati k poznavanju njihove letne dinamike pojavljanja v nekaterih dolenjskih kraških jamah.

Kraške jame so za netopirje pomembna zatočišča, saj se vanje zatekajo prek celega leta. Da bi ugotovili, kakšno vlogo imajo jame v življenju netopirjev, smo leta 1994 spremljali značilnosti letne dinamike njihovega pojavljanja v najpomembnejših zatočiščih na Dolenjskem: Jazbini, Lukenjski jami ter turistično urejenima Kostanjeviški in Krški jami. Pri opazovanju smo se osredotočili na vrste iz družine podkovnjakov, ki tudi

sicer prevladujejo v jamah na Dolenjskem. Te si po čivališča praviloma izbirajo na izpostavljenih delih podzemskih dvoran, kjer so zaradi pogostih obiskov in osvetljevanj moteni. Dobljene podatke smo uporabili kot izhodišča za izdelavo naravovarstvenih smernic pri upravljanju in varstvu jam. V prispevku navajamo tudi druge opažene vrste netopirjev.

### OPIS OBRAVNAVANEGA OBMOČJA

#### Značilnosti opazovanih jam

**Jazbina**, severno vznožje Kočevskega Roga, pri vasi Podturn. Je 120 metrov dolga suha vodoravna jama. Vhodni rov je prostoren, srednji del je ozek in težko prehodan erozijski rov, zaključuje pa se z večjo podorno dvorano. Jama je na več mestih lepo zasigana in zaradi bližine vasi tudi pogosto obiskana.

**Luknja**, izvorna jama v zatrepi dolini reke Temenice pri Novem mestu. Dolga je dobrih 50 metrov. Za ožjim vhomom je večja vhodna dvorana, ki po krajšem erozijskem rovu prehaja v končno kapniško dvorano s sifonskim jezerom.

**Kostanjeviška jama**, vodna jama v vznožju Gorjancev pri Kostanjevici na Krki. Meri prek 1500 metrov in je ena večjih na Dolenjskem. V jami se menjavajo aktivni, občasno poplavni in fosilni vodni rovi. V

vhodnem delu je jama v dolžini 300 metrov urejena za turistične obiske.

**Krška jama**, izvorna jama reke Krke. Jama je vodotrajna, dolga 220 metrov, zaključuje pa se s sifonskim jezerom. Za vhomom se razširi v podorno dvorano, ki se pod stropom odpira z manjšim vhomom. Ta del je za netopirje tudi najbolj zanimiv. Jama je bila pred nekaj leti turistično urejena, oba vhoda pa zaprta z rešetkami.

**Tab. 1: Letna dinamika pojavljanja podkovnjakov - Jazbina.**

**Tab. 1: Annual dynamics of the occurrence of horseshoe bats - cave Jazbina.**

| vrsta/species - datum/date                    | 1.2. | 8.3. | 9.4. | 8.5. | 5.6. | 6.7.     | 19.8. | 16.9. | 15.10. | 19.11.1994 |
|---|------|------|------|------|------|----------|-------|-------|--------|------------|
| mali podkovnjaki<br><i>R. hipposideros</i>    | 11   | 5    | 9    | 3    | 2    | 1        | 2     | 12    | 18     | 14         |
| veliki podkovnjaki<br><i>R. ferrumequinum</i> | 147  | 147  | 93   | 45   | 60   | 1<br>40* | 6     | 18    | 160    | 190        |

\* porodniška kolonija (*maternity colony*)

**Tab. 2: Letna dinamika pojavljanja podkovnjakov - Luknja.**

**Tab. 2: Annual dynamics of the occurrence of horseshoe bats - cave Luknja.**

| vrsta/species<br>datum/date                   | 1.2.1994 | 16.3. | 9.4. | 8.5. | 5.6. | 6.7.     | 4.8. | 19.8. | 14.9. | 15.10. | 14.11. |
|---|----------|-------|------|------|------|----------|------|-------|-------|--------|--------|
| mali podkovnjaki<br><i>R. hipposideros</i>    | 7        | 3     | 4    | 2    | 2    | 1        | 2    | 2     | 1     | 10     | 2      |
| veliki podkovnjaki<br><i>R. ferrumequinum</i> | 14       | 16    | 126  | 120  | 1    | 2<br>30* | 2    | 2     | 30    | 85     | 2      |

\* porodniška kolonija (*maternity colony*)

**Tab. 3: Letna dinamika pojavljanja podkovnjakov - Kostanjeviška jama.**

**Tab. 3: Annual dynamics of the occurrence of horseshoe bats - cave Kostanjeviška jama.**

| datum/date<br>vrsta/species                  | 2.2.1994 | 13.3. | 10.4. | 15.5. | 3.7. | 21.8. | 24.9. | 22.10. | 27.11. |
|--|----------|-------|-------|-------|------|-------|-------|--------|--------|
| mali podkovnjak<br><i>R. hipposideros</i>    | 10       | 0     | 2     | 0     | 0    | 0     | 0     | 1      | 1      |
| južni podkovnjak<br><i>R. euryale</i>        | 150      | 0     | 66    | 0     | 0    | 0     | 2     | 250    | 280    |
| veliki podkovnjak<br><i>R. ferrumequinum</i> | 48       | 60    | 2     | 5     | 0    | 0     | 4     | 20     | 57     |

**Tab. 4: Letna dinamika pojavljanja podkovnjakov - Krška jama.**

**Tab. 4: Annual dynamics of the occurrence of horseshoe bats - Krška jama.**

| vrsta/species<br>datum/date                  | 1.2.1994 | 17.4. | 15.5. | 17.8. | 29.9. | 30.10. | 19.11. |
|--|----------|-------|-------|-------|-------|--------|--------|
| mali podkovnjak<br><i>R. hipposideros</i>    | 17       | 2     | 0     | 0     | 5     | 25     | 24     |
| veliki podkovnjak<br><i>R. ferrumequinum</i> | 5        | 2     | 0     | 0     | 10    | 9      | 9      |

## METODA

V izbranih jamah smo netopirje popisali enkrat mesečno od februarja do novembra 1994 med 9. in 15. uro. Osebkke posameznih vrst smo prešteli, v primeru zgoščenih kolonij pa tudi fotografirali. Da bi dobili podrobnejši vpogled v število tam živečih osebkov in vrst, smo v poletnem obdobju pred jamami tudi lovili z mrežo.

## REZULTATI IN RAZPRAVA

### Jazbina

V jami smo redno opazovali velike in male podkovnjake. Največ netopirjev je bilo zabeleženih v času prezimovanja. Veliki podkovnjaki so prezimovali v strnjeni koloniji v podorni dvorani na koncu jame, mali podkovnjaki pa posamič po vsej jami. Junija je bila krajše obdobje v vhodnem delu tudi porodniška kolonija velikih podkovnjakov. Obe lokaciji sta bili visoko pod stropom in varni pred obiskovalci.

6. julija in 19. avgusta smo lovili z mrežo pred jamo. Iz jame je v mraku zleto večje število netopirjev (vsaj okoli 30), medtem ko so bili ob pregledu jame opaženi le redki. Z mrežo je bilo ulovljenih prvič pet in drugič šest velikih podkovnjakov, ki so prileteli iz jame. 19. avgusta je bil ujet tudi obvodni netopir *Myotis daubentoni*, ki je letel v jamo.

### Luknja

V jami so prevladovali veliki podkovnjaki. Največ smo jih opazili v prehodnem obdobju - pomladi in jeseni - pozimi pa veliko manj. Malih podkovnjakov je bilo občutno manj, občasno pa smo opazili tudi posamezne gladkonose netopirje: obvodne *M. daubentoni* in dolgo-krile *Miniopterus schreibersi*. Veliki podkovnjaki so se praviloma zadrževali v končni dvorani, julija pa je bila pod vhodnim spodmolom opažena manjša porodniška kolonija, ki se je sicer zadrževala v razvalinah bližnjega gradu.

Lov z mrežo pred jamo je bil opravljen 2. oktobra. V 25 minutah je bilo ujetih 33 velikih podkovnjakov. Več osebkov se je ujelo z zunanje strani. Iz jame je priletel v mrežo tudi *Myotis daubentoni*.

### Kostanjeviška jama

V jami so bili ob obiskih zabeleženi mali in veliki podkovnjaki, prevladujoči pa so bili južni podkovnjaki (do 280). Veliki podkovnjaki so prezimovali v turističnem delu pod stopnicami, južni podkovnjaki pa v Podorni dvorani, kjer jih turistično obiskovanje in osvetljevanje jame ni motilo. Večje količine iztrebkov so bile opažene tudi v Kapniški dvorani, vendar netopirjev tu nismo opazili.

Lov z mrežo je bil opravljen 3. julija in 24. septembra pred vhodom v jamo. Čeprav so bile jame ob pregledih skorajda prazne, je lov pokazal, da se v jami zadržuje manjše število vseh treh vrst podkovnjakov, veliko pa jih je priletelo tudi do jame.

### Krška jama

Kljub velikim količinam iztrebkov, ki so vidni na vzhodnem obrobju vhodne dvorane, smo opazili malo netopirjev. Jama je za podkovnjake pomembna predvsem v času prezimovanja. Več je bilo malih podkovnjakov, nekoliko manj velikih, ki pa niso bili nikdar združeni v koloniji. Opažena sta bila tudi dolgonogi netopir *Myotis capaccinii* in navadni netopir *M. myotis*.

### Značilnosti letne dinamike pojavljanja podkovnjakov v jamah

#### Velik podkovnjaki *Rhinolophus ferrumequinum*

Opazovanje letne dinamike pojavljanja velikih podkovnjakov v opazovanih jamah kaže, da so se v jame najbolj množično zatekali od oktobra do začetka aprila, v poletnih mesecih pa so jame zapustili. Hibernacija je trajala od novembra do začetka marca, ko prezimujoče kolonije niso spreminjale svoje lege in številnosti. Za hibernacijo so si veliki podkovnjaki izbrali izpostavljena mesta na stropu dvoran, kamor ne sežejo vplivi zunanjih temperatur. Izjema je bila Luknja, v kateri so bili številčni vrhunci doseženi v prehodnem obdobju aprila in oktobra. Spomladi so se kolonije postopno manjšale, veliki podkovnjaki pa so bili opaženi po vsem jamskem poligonu. Topli vhodni deli so rabili kot zatočišča porodniških kolonij v Jazbini in Luknji.

Lov z mrežo v poletnih mesecih je potrdil pojavljanje manjšega števila osebkov v jamah, veliko pa jih je zvečer priletelo na ogled vhodnih delih jam. Septembra se je število velikih podkovnjakov v vseh jamah začelo povečevati, tako da so oktobra ponovno oblikovali približno enako velike zimske kolonije.

#### Mali podkovnjaki *Rhinolophus hipposideros*

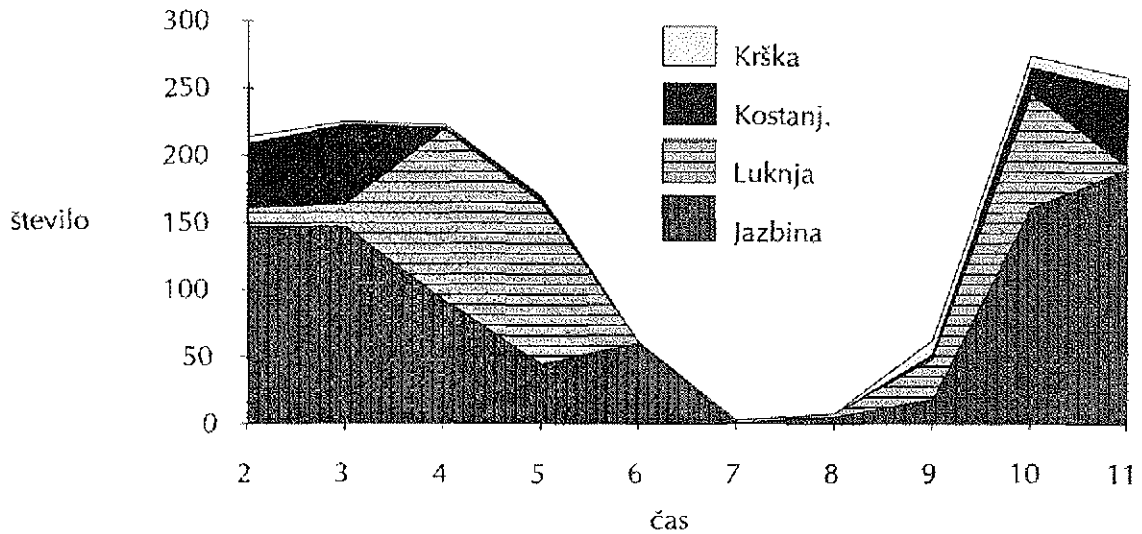
Malih podkovnjakov je bilo v opazovanih jamah na splošno veliko manj kot velikih, a lahko kljub temu razberemo podobno sezonsko ritmiko. Tudi pri njih igrajo jame ključno vlogo v času prezimovanja od oktobra do začetka marca. V nasprotju z velikimi so bili mali podkovnjaki posamično raztreseni po vsem jamskem poligonu, številni med njimi pa so se med posameznimi zimskimi popisi premaknili. Spomladi je njihovo število hitreje upadlo kot pri velikih podkovnjakih, tako da so bili poleti v jamah opaženi le redki. Lov z mrežo v poletnih mesecih je potrdil, da se zadržujejo v jamah, septembra pa so se začeli postopno vračati.

Južni podkovnjaki *Rhinolophus euryale*

Za ugotavljanje značilnosti letne dinamike južnih podkovnjakov bi bilo potrebnih več opazovanj, na splošno pa lahko rečemo, da se kaže podobna dinamika kot pri sorodnih vrstah podkovnjakov. V času prezimovanja so oblikovali kolonijo, vendar se niso zgneti

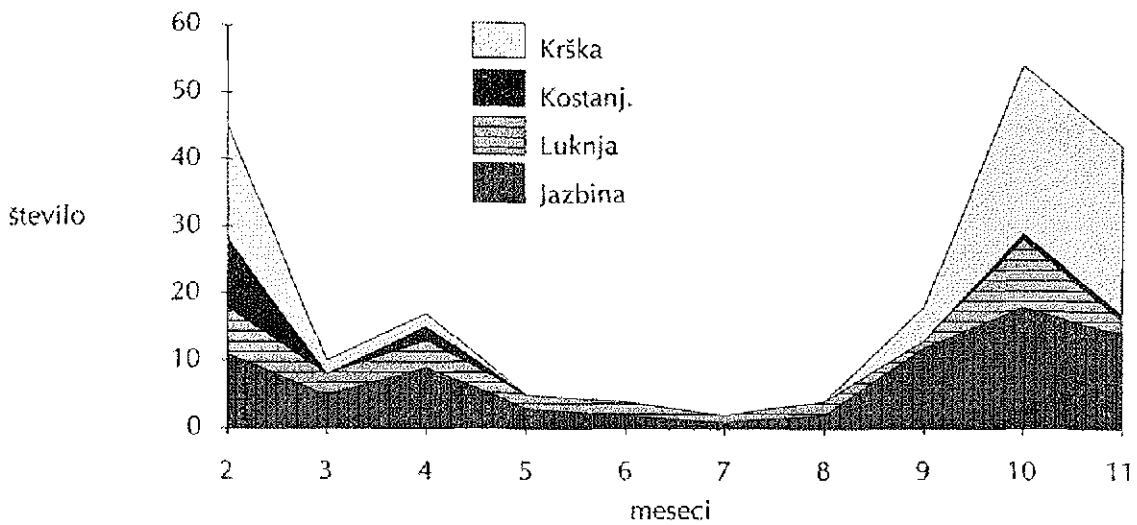
tesno skupaj. Ob zimskih popisih je bilo videti, da ne spijo tako trdno, saj se je obris kolonije spreminjal, tako kot tudi njena lega. Kolonija se je razbila že sredi marca, tako da jih v jami ni bilo opaziti od maja do septembra. Tudi tu je lov z mrežo potrdil navzočnost posameznih osebkov prek poletja in pogoste obiske od zunaj.

veliki podkovnjaki

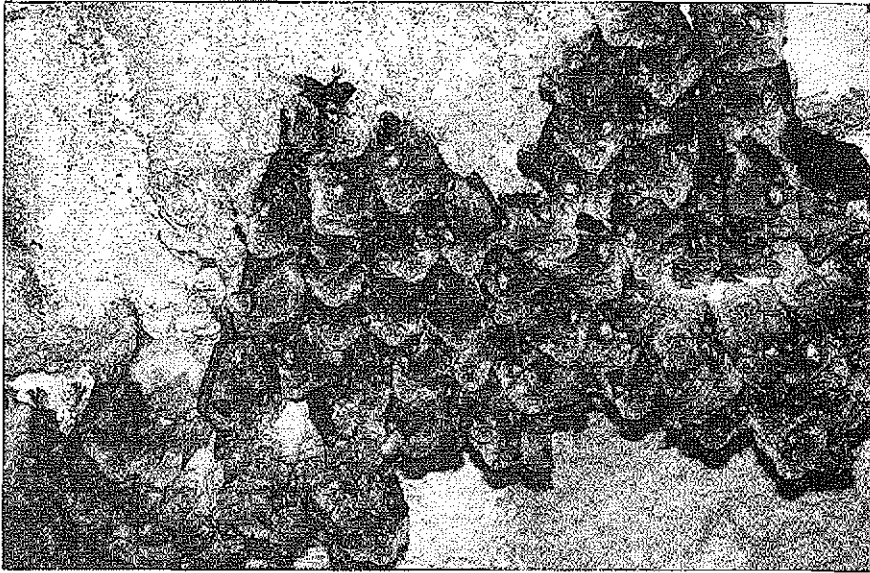


Sl. 1: Veliki podkovnjaki, letna dinamika.  
Fig. 1: Great horseshoe bats, annual dynamics.

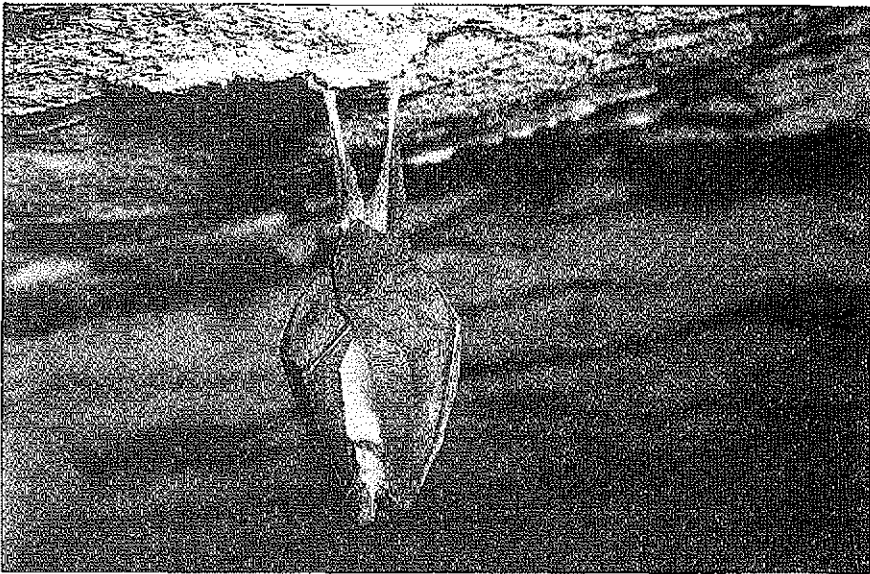
mali podkovnjaki



Sl. 2: Mali podkovnjaki, letna ritmika.  
Fig. 2: Little horseshoe bats, annual dynamics.



Sl. 3: Kolonija velikih podkvnjakov v Jazbini (Foto: A. Hudoklin).  
 Fig. 3: A colony of great horseshoe bats in the cave Jazbina (Photo: A. Hudoklin).



Sl. 4: Mali podkvnjak (*Rhinolophus hipposideros*) v jami Luknja (Foto: A. Hudoklin).  
 Fig. 4: Lesser horseshoe bat in the cave Luknja (Photo: A. Hudoklin).

#### ZAKLJUČEK

Spremljanje letne dinamike pojavljanja podkvnjakov v izbranih jamah je pokazalo, da jim te z izjemo vročih poletnih mesecev pomenijo pomembno zatočišče prek celega leta. V jamah Jazbina, Lukenjska in Krška jama so bili opazovani veliki podkvnjaki *Rhinolophus ferrumequinum* in mali podkvnjaki *R. hipposideros*, v turistično urejeni Kostanjeviški jami pa tudi južni podkvnjaki *R. euryale*.

Pri opazovanih vrstah podkvnjakov je bila zabeležena podobna sezonska dinamika. Največ netopirjev je bilo v jamah od oktobra do aprila, do junija pa so se postopoma umaknili iz jam. V tem času pa so bile v vhodnem delu Luknje in Jazbine opažene rodniške kolonije velikih podkvnjakov. Najmanj podkvnjakov smo zabeležili v jamah julija in avgusta, ko jih ob pregledih praktično ni bilo. Lov z mrežo je kljub temu potrdil navzočnost sicer manjšega števila osebkov, a tudi pogoste obiske netopirjev od zunaj. Septembra so

se podkvnjaki začeli postopno zbirati v jamah, oktobra pa so bile kolonije že polnošteviline.

Opazovane jame si zaradi stalne navzočnosti netopirjev zaslužijo posebno naravovarstveno pozornost. V neturistični Luknji in Jazbini je treba zagotoviti nadzorovan vstop ali njihovo zaprtje, v primeru turističnih urejene Kostanjeviške in danes tudi Krške jame pa se je treba z upravljalcem dogovoriti o režimu obiskovanja in osvetljevanja.

## ZAHVALA

Prispevek je povzet po raziskovalni nalogi "Evideniranje prezimovališč netopirjev", ki jo je leta 1994 finančno omogočila Občina Novo mesto. Za strokovno pomoč pri izvedbi naloge se zahvaljujem dr. Borisu Kryštufku.

## ANNUAL DYNAMICS OF THE OCCURRENCE OF HORSESHOE BATS (*RHINOLOPHUS* SPP.) IN SOME CAVES OF DOLENJSKA

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### SUMMARY

*In 1994, characteristics of the annual dynamics of occurrence of horseshoe bat populations in their most important cave shelters in the Dolenjska region were studied. In the caves Jazbina, Lukenjska jama and Krška jama, individuals of the species *Rhinolophus ferrumequinum* and *R. hipposideros* were present through the entire year, while in the cave Kostanjeviška jama (accessible for tourists) the species *R. euryale* were recorded as well.*

*In the observed species, similar dynamics in their occurrence was noted throughout the year. The greatest numbers of bats in the caves were recorded at the time of hibernation, i.e. from November to early March, and during the following three months their numbers gradually decreased. In June some maternity colonies of great horseshoe bats were also observed in the eastern part of Jazbina and Lukenjska jama. The lowest numbers of horseshoe bats in the caves were recorded in July and August, when there were practically none. Net hunting still confirmed the presence of indeed smaller number of individuals, but some frequent visits by them from outside as well. In September the horseshoe bats began to gather in these caves gradually, and by October the colonies were full-numbered. The obtained data were used as a background in the preparation of nature conservation guidelines in the management and protection of caves.*

**Key words:** horseshoe bats, *Rhinolophus*, Chiroptera, annual dynamics, Dolenjska

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ASSOCIATIONS**



**United Nations Environment Programme  
Mediterranean Action Plan**

**Alenka Malej<sup>1</sup>, Mitja Bricelj<sup>2</sup>**

**SREDOZEMSKI AKCIJSKI NAČRT (MAP) IN PROGRAM  
MED POL V SLOVENIJI**

Morja so stoletja oblikovala način življenja in kulturo obmorskih ljudstev; v moderni dobi pa se je začel povečevati tudi vpliv ljudi na morja. Z naraščanjem števila prebivalcev na obalah, s hitrim tehnološkim razvojem, gostejšim pomorskim prometom, intenzivnejšim ribištvom in marikulturo, vedno večjimi količinami odpadkov in razvojem množičnega turizma so se problemi v morskem okolju pričeli kopičiti. Sredozemsko območje z večtisočletno civilizacijo in pestrostjo dejavnosti na obalah in morju je postalo primer razvoja na račun zanemarjanja okolja in pesimistični strokovnjaki so mu pred nekaj desetletji prerokovali črno usodo. Z naraščanjem problemov v okolju je v mednarodni skupnosti dozorelo spoznanje, da je sodelovanje pri preprečevanju ter odpravljanju posledic onesnaženja okolja nujnost, saj so raziskave in meritve onesnaženja pokazale, da se splošno stanje okolja resno poslabšuje. Prelomnica na tem področju je bila konferenca Združenih narodov o okolju v Stockholmu l. 1972: ustanovljen je bil program Združenih narodov za okolje (United Nations Environmental Programme - UNEP). Kmalu je bil vzpostavljen tudi program za regionalna morja (Regional Seas Programme - RSP) z namenom izboljšati sodelovanje pri varovanju morja in obalnih območij. Danes v različnih programih, npr. za Rdeče morje, Črno morje, Perzijski zaliv in drugih, skupno sodeluje prek 120 držav.

Med prvimi je bil vzpostavljen regionalni program za Sredozemsko morje (Charpentier, 1997). Leta 1975 je bil v okviru UNEP-a na zasedanju 16 sredozemskih držav in Evropske komisije v Barceloni sprejet Sredozemski akcijski načrt (Mediterranean Action Plan - MAP); že naslednje leto pa so, prav tako v Barceloni, sredozemske države in Evropska komisija podpisale Konvencijo o varovanju Sredozemskega morja pred onesnaženjem (Barcelonska konvencija). Barcelonska konvencija je postala pravni okvir MAP-a in je začela

veljati leta 1978. Istočasno sta bila sprejeta dva protokola: Protokol o preprečevanju onesnaženja s plovil in letal ter Protokol o sodelovanju pri onesnaženju morja v primeru nesreč. Cilji prve faze MAP-a (1976-1995) so bili:

- pomoč sredozemskim državam pri raziskavah, oceni in kontroli onesnaženja Sredozemskega morja,
- pomoč pri opredelitvi nacionalnih politik za varovanje morja,
- pomoč pri pripravi alternativnih možnosti razvoja in celovitega gospodarjenja z obalnimi območji.

Republika Slovenija (po načelu nasledstva) od 15. marca 1994 enakopravno sodeluje v krogu sredozemskih držav, ki jih zajema MAP.

Usklajevanje akcijskega načrta je bilo zaradi različne razvitosti sredozemskih držav in političnih nesoglasij težavno in je do neke mere vplivalo na uspešnost prve faze programa (Kečkeš, 1997). Vendar pa je vsekakor treba poudariti tudi uspehe: pridobivanje realnejše slike o stopnji obremenitve in onesnaženja Sredozemskega morja, povečanje znanja in opremljenosti laboratorijev v manj razvitih sredozemskih državah, usklajevanje politik pri varovanju morja in boljša pripravljenost na nesreče, mednarodno sodelovanje in skupne akcije v primerih onesnaženja, začetek priprav meddržavnih programov gospodarjenja z morjem in obalami. Za izboljšanje koordinacije MAP-a je bila leta 1982 v Atenah vzpostavljena Koordinacijska enota (Coordination Unit for the Mediterranean Action Plan), ki deluje kot sekretariat za implementacijo dejavnosti sprejetih v okviru Barcelonske konvencije. Različni regionalni centri, ki so bili vzpostavljeni v okviru MAP-a pa nudijo strokovno pomoč pri realizaciji programa.

Že l. 1977 sta bila ustanovljena regionalna centra za prioritetne akcije (Priority Action Programme - PAP/RAC) s sedežem v Splitu in center za načrtovanje razvoja (Blue Plan - BP/RAC) s sedežem v Sophii Antipolis v bližini Nice. L. 1978 je bil vzpostavljen regionalni center na Malti, ki je l. 1989 prerasel v center REMPEC (Regional Marine Pollution Emergency Response Centre) in tesno sodeluje z IMO (International Maritime Organization). Danes za strokovno podporo pri uresničevanju akcijskega načrta MAP-a delujejo poleg omenjenih treh centrov še: regionalni center za zaščiteni območja v Tunisu (Specially Protected Areas - SPA/RAC), center za oddaljeno zaznavanje okolja v Palermu (Environmental Remote Sensing - ERS/RAC), ter center za čistejšo tehnologije v Barceloni (Cleaner Production - CP/RAC), v Marseillu pa sekretariat za zgodovinske centre (100 Historic Sites Secretariat). Omenjeni centri prirejajo tematske delavnice za izobraževanje nacionalnih strokovnjakov, dajejo strokovno pomoč državam

<sup>1</sup> Nacionalna koordinatorica za MED POL, Morska biološka postaja, Nacionalni inštitut za biologijo.

<sup>2</sup> Koordinator/središčno mesto za MAP, Ministrstvo za okolje in prostor R Slovenije.

pogodbenicam ter razvijajo metode za doseganje ciljev MAP-a. Celotna institucionalna struktura Sredozemskega akcijskega načrta (MAP-a) je prikazana na sliki 1 (po Charpentier, 1997).

Leta 1988 sta Svetovna banka in Evropska investicijska banka osnovali Sredozemski program (Mediterranean Environment Programme - MEP) in l. 1990 je pričel delovati program tehnične pomoči za sredozemsko okolje (Mediterranean Environment Technical Assistance Programme - METAP). Istega leta so se sredozemske države z Nikozijsko listino (Nicosia Charter) obvezale, da bodo pripravile skupno dolgoročno strategijo za razvoj in ob tem upoštevale načela integralnega gospodarjenja z morjem in obalami. METAP predvsem zagotavlja investicije v okolje npr. samo l. 1995 za okoli 100 projektov v sredozemskih državah.

V prvi polovici 90-ih let se je začela priprava druge faze MAP-a. Pomembna izhodišča za pripravo MAP II so bili zaključki Konference Združenih narodov o okolju in razvoju (Rio de Janeiro, l. 1992) predvsem Agenda 21 ter konvenciji o biodiverziteti in klimatskih spremembah. Sredozemske države so l. 1994 v Tunisu organizirale konferenco na ministrski ravni, ki je obravnavala trajnostni razvoj v sredozemskem bazenu. Na tej konferenci sta bila sprejeta dokument Agenda MED 21 in odločitev o ustanovitvi Sredozemske komisije za trajnostni razvoj (MCSO).

Vseskozi so sredozemske države dopolnjevale tudi pravni okvir MAP-a: ob dvajsetletnici delovanja so na zasedanju v Barceloni (1995) sprejele Akcijski načrt za varovanje morsklega okolja in trajnostni razvoj obalnih območij Sredozemlja in tudi dokument o prednostnih področjih delovanja v okviru druge faze Sredozemskega akcijskega načrta. Nekateri protokoli, sprejeti v prvi fazi MAP-a, so bili dopolnjeni (Protokol o preprečevanju onesnaženja s plovil in letal, Protokol o sodelovanju pri onesnaženju morja v primeru nesreč, Protokol o zaščiti Sredozemskega morja pred onesnaženjem s kopnega - protokol LBS), sprejeti pa so bili tudi novi: Protokol o zaščitenih območjih in biodiverziteti, Protokol o zaščiti Sredozemskega morja pred onesnaženjem zaradi izkoriščanja kontinentalne police in morsklega dna ter Protokol o preprečevanju onesnaženja Sredozemskega morja zaradi prekmernega prevoza nevarnih odpadkov.

Leta 1996 se je tako pričela druga faza programa Sredozemskega akcijskega načrta (MAP II), katerega cilji so:

- zagotoviti trajnostno gospodarjenje z morskimi in obalnimi viri,
- zaščititi morsko okolje in obalna območja pred onesnaženjem z zmanjševanjem oz. eliminacijo virov onesnaženja,
- zaščititi naravo in območja posebne ekološke in/ali kulturne vrednosti,
- prispevati k izboljšanju kakovosti življenja.

Prednostna področja delovanja MAP II (1996-2005)

so predvsem: priprava nacionalnih strategij trajnostnega razvoja, celovito gospodarjenje z naravnimi viri in obalnimi območji, integracija sektorskih dejavnosti za varovanje morsklega in obalnega okolja (kmetijstva, industrije, prometa, turizma, poseljevanja), ocena in kontrola onesnaženja, racionalno gospodarjenje z odpadki, razvoj informacijskega sistema in zaščita krajine ter ekološko ali kulturno pomembnih lokacij.

Skladno s temi izhodišči je slovenska delegacija na 11. rednem zasedanju držav pogodbenic Barcelonske konvencije (Malta, 27. - 30. 10. 1999) predstavila stališča Vlade R Slovenije do okolja in trajnostnega razvoja v Sredozemlju (UNEP, 1999a):

1. Republika Slovenija ima 46,6 km obale v Tržaškem zalivu, ki ga deli z Republiko Hrvaško in Republiko Italijo. Pomorski promet, kmetijstvo, industrija, urbanizacija in turizem imajo velik vpliv na okolje, ki se pogosto kaže kot degradacija naravnih virov in habitatov. Slovenija pri pripravi prostorskih planov upošteva načela trajnostnega razvoja in zato je domala četrtnina obale že razglašena za zavarovano območje. 1992 je bilo območje Sečoveljskih solin uvrščeno na Ramsarsko listo mokrišč mednarodnega pomena ter 1996 ustanovljen Regionalni park Škocjanske jame, ki so uvrščene na UNESCO-v seznam svetovne dediščine.

2. Slovenija je z namenom, da uresniči načela trajnostnega razvoja v zaščitenih območjih, začela s pripravo celovitih vodnogospodarskih osnov reke Dragonje. Dolina Dragonje, ki meji na Hrvaško, je ena najbolj ohranjenih ob Jadranu. V zadnjih petdesetih letih se delež gozda v njej veča in sestavlja že 60 % površja.

3. Slovenija ima na svoji obali namen uveljaviti načela in metode celostnega upravljanja s porečji in obalnimi območji, vključno z izdelavo upravljalških načrtov in aktivnim sodelovanjem javnosti. To je proces, ki obsega obravnavo naravnih, ekonomskih in socialnih vsebin, na katerih temelji trajnostni razvoj.

4. Ustanovitev Regionalne razvojne agencije v Kopru bo pripomogla k usklajevanju ekonomskih razvojnih pobud z upoštevanjem zmogljivosti okolja. Z ustanovitvijo agencije bo dosežen tudi cilj iz Nacionalnega programa varstva okolja, ki nalaga izboljšanje upravnega delovanja na regionalni ravni kot predpogoj za celostno upravljanje z obalnim območjem, vključno s priporočili in smernicami Mediteranske komisije za trajnostni razvoj za uvedbo in spremljanje okoljskih indikatorjev.

5. REMPEC (Marine Pollution Emergency Response Centre) je pripravil strokovna izhodišča za oceno varnosti in ravnanja v primeru nesreč s tekočimi kemikalijami v Luki Koper. Uresničitev te naloge bi povišala okoljsko - varnostne standarde Luke.

6. Trilateralna komisija za varstvo Jadranskega morja (Slovenija - Hrvaška - Italija) se sestaja redno in ima

delovne skupine za: kakovost Jadranskega morja, načrt sodelovanja v primeru onesnaženj in sistem ločene plovbe za zmanjšanje okoljskih tveganj. Junija 1999 je komisija sprejela stališče o izdelavi skupne študije o severnem Jadranu kot podlagi za odločanje o možni proglasitvi severnega Jadrana za "občutljivo območje/sensitive area". Slovenija je to pobudo tudi uradno predlagala kot vsebino MAP-a v obdobju 2000-2001.

Program MED POL, ki ponazarja znanstveno-tehnično komponento MAP-a, je vseskozi pomemben del Sredozemskega akcijskega načrta. Program MED POL je bil vzpostavljen l. 1975, cilji prve faze (1975-1980) pa so bili:

- izoblikovati in izvajati usklajen program spremljanja onesnaženja morja ter opraviti na tem področju dopolnilne raziskave,
- pomagati nacionalnim centrom pri razvoju (kadrovskem in v opremi) za kakovosten monitoring morja,
- analizirati vire, količine, stopnje in trende onesnaževalnih snovi v Sredozemskem morju,
- zagotoviti znanstveno-tehnične informacije, ki jih potrebujejo vlade sredozemskih držav in Evropske skupnosti za uresničevanje Barcelonske konvencije,
- zagotoviti zadostno časovno serijo zanesljivih podatkov o virih, količinah, stopnji onesnaženja ter prispevati k znanstvenim spoznanjem o Sredozemskem morju.

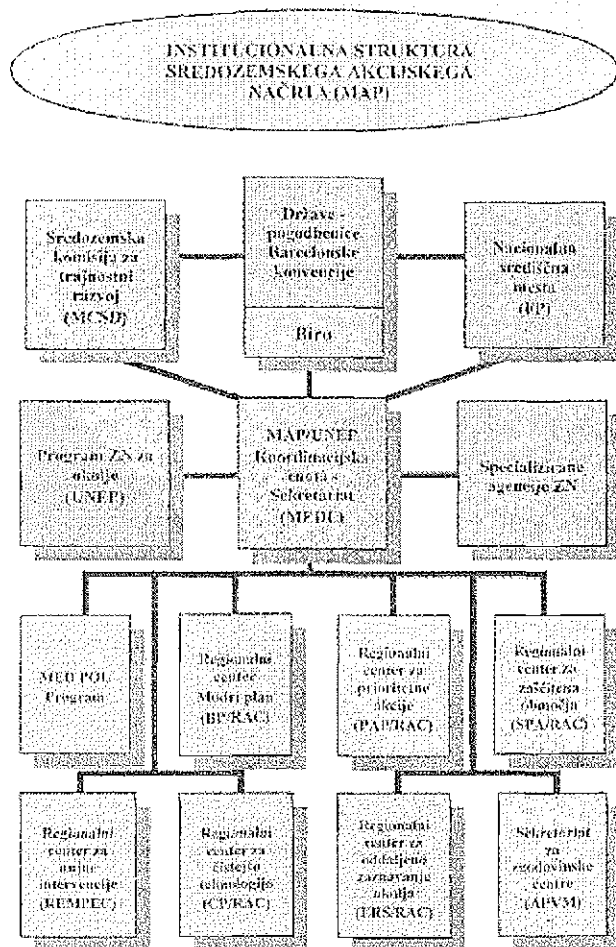
Pri prvi fazi programa MED POL je sodelovalo 83 raziskovalnih centrov iz 15 sredozemskih držav (okoli 200 raziskovalcev). Druga faza programa MED POL (Dolgoročni program raziskav in spremljanje onesnaženja Sredozemskega morja, MED POL II) je bila sprejeta marca 1981. Poleg okvirne dolgoročne naloge, tj. preprečevanje onesnaženja Sredozemskega morja v skladu z Barcelonsko konvencijo, so bili za program MED POL II opredeljeni sledeči specifični cilji:

- zagotoviti potrebne informacije za uresničevanje Barcelonske konvencije in protokolov,
- opredeliti kazalce učinkovitosti ukrepov, ki so bili sprejeti v okviru Barcelonske konvencije in protokolov,
- zagotoviti znanstvene osnove za revizijo in dodatke k Barcelonski konvenciji in obstoječih protokolov ter pripravo novih protokolov,
- pripraviti osnove za racionalno gospodarjenje z obalnimi območji v skladu s trajnostnim razvojem, in sicer na nacionalnem in multilateralnem nivoju,
- periodično zagotavljati oceno stanja onesnaženosti Sredozemskega morja.

Do konca leta 1995 sta imeli dve tretjini sredozemskih držav vzpostavljen dolgoročni program spremljanja onesnaženja; potekalo pa je tudi prek 40 raziskovalnih projektov, ki so analizirali različne vidike onesnaženja morja. Na osnovi izkušenj prve in druge faze MED POL programa, se je l. 1997, z enoletnim odlogom, pričela tretja faza (1996-2005). Težišče programa tretje faze MED POL je na kontroli onesnaženja

in usposabljanju držav pogodbenic Barcelonske konvencije za čim uspešnejše opravljanje obveznosti iz protokola LBS (Protokol o zaščiti morja pred onesnaženjem s kopnega). Zato so države pogodbenice na zasedanju v Tunisu (1997) sprejele strateški načrt akcij (SAP), ki ga finančno podpira tudi projekt GEF (Global Environment Facility). V celoti naj bi bil ta načrt za zmanjšanje oz. eliminacijo virov onesnaženja Sredozemskega morja s kopnega zaključen v prihodnjih 25-ih letih. Zato bo za uresničevanje SAP-a sekretariat MAP-a v obdobju 2000-2001 pripravil vrsto priporočil in navodil ter organiziral delavnice in druge oblike izobraževanja kot pomoč državam pogodbenicam Barcelonske konvencije. Novost v programu MED POL III je tudi uvajanje biomonitoringa, tj. spremljanja bioloških učinkov onesnaženja na morskih organizmih in pa večji poudarek na ugotavljanju dolgoročnih sprememb (trendov) stopnje onesnaženja morja.

Vlada R Slovenije je na svoji seji 28. decembra 1999 potrdila nacionalni program MED POL (UNEP, 1999b). Le-ta vključuje spremljanje virov onesnaženja s kopnega, žarišč onesnaženja (podvodni izpusti, rečna ustja, pristanišče Koper, marine), spremljanje voda, name-



njenih vzgoji morskih organizmov, spremljanje kopaljskih voda in stanja obalnega morja (spremljanje stopnje onesnaženja organizmov in sedimenta s težkimi kovinami in ogljikovodiki), dolgoročno spremljanje trofičnega stanja obalnega morja in biomonitoring za oceno bioloških posledic onesnaženja na morskih organizmih. Zbrane podatke izvajalci monitoringa posredujejo Ministrstvu za okolje in prostor ter koordinacijski enoti - sekretariatu MAP-a v Atene. Zelo pomemben je tudi program za zagotavljanje kakovosti podatkov. Poleg tega je v okviru programa MED POL treba periodično pripraviti nacionalni pregled točkovnih in netočkovnih virov onesnaženja na kopnem, kot so opredeljeni v protokolu LBS, in poročati o drugih, za kakovost morja relevantnih dejavnostih ter vsake 4 leta pripraviti nacionalno poročilo o stanju morskega in obalnega okolja. Po drugi strani pa sekretariat MAP-a zagotavlja državam podporo in pomoč pri uresničevanju programa MED POL in drugih dejavnosti v okviru MAP-a.

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**Boris Petelin**

WORKSHOP ON BENEFITS OF THE  
IMPLEMENTATION OF THE GLOBAL OCEAN  
OBSERVING SYSTEM IN THE MEDITERRANEAN  
REGION, RABAT - Morocco, 1-3 November 1999

From 1-3 November 1999 I represented Slovenia at the Workshop on Benefits of the Implementation of the Global Ocean Observing System in the Mediterranean Region, which was held in Rabat, Morocco.

The Global Ocean Observing System (GOOS) an international program promoted by the Intergovernmen-

tal Oceanographic Commission (IOC), the World Meteorological Organisation (WMO), the United Nations Environment Program (UNEP) and the International Council of Science (ICSU).

The mission of GOOS is to prepare a permanent global framework for observing, modelling and analysing ocean variables in order to provide service and benefits to governments, marine industries, environmental management, fisheries, climate prediction, public health, safety at sea, coastal defences, tourism, wildlife conservation, shipping and port operations, agriculture and the management of energy supply.

MedGOOS is Mediterranean component of GOOS and concerns all countries bordering on the Mediterranean Sea. The participants at the Workshop were from Algeria, Morocco, France, Egypt, Italy, Libya, Malta, Greece, Tunisia, Lebanon, Bosnia-Herzegovina, Syria, Croatia, Slovenia, Israel, Turkey, Palestine and Cyprus and also from United Kingdom, South Africa, Belgium, Kenya and the Netherlands.

After the plenary lectures and presentation of Mediterranean projects, a presentation of national activities by southern and eastern Mediterranean countries took place. I was given an opportunity to present the Coastal Oceanographic Station Piran - Development of Operational Oceanography in Slovenia.

The Marine Station Piran of the National Institute of Biology is researching and monitoring the oceanographic and ecological parameters in the southern part of the Gulf of Trieste. It is closely collaborating with similar institutions in the neighbouring countries - Italy and Croatia. The continuous needs of the oceanographic and ecological parameters resulted in a project proposal for the Coastal Oceanographic Station Piran (COSP).

The objective of the project is to set up an oceanographic and monitoring system, which would allow:

- Oceanographic and ecological study of the shallow Gulf of Trieste
- Pollution prevention
- Immediate intervention in the case of potential ecological catastrophes
- General safeguarding of the sea
- Improvement of the Vessel Traffic System to improve the manoeuvring

The data will be available to various research institutions of the neighbouring countries, the oceanographic and meteorological communities, town halls, regional and state agencies, working on pollution problems and educational organisations.

- Coastal Oceanographic Station Piran will consist of:
- Coastal oceanographic buoy with measuring and communication equipment
  - Land station at the Marine Station Piran

The buoy will be located 1.4 mile off the tip of Piran in the direction of Grado and 2.1 miles off the Marine Station Piran and five miles off the neighbouring coun-

tries of Italy and Croatia. It will be moored in a shallow area (at a depth of 22 m) with flat muddy (silty-sand) bottom. It will measure the oceanographic and ecological parameters of the sea and marine meteorological parameters above it.

The Telemetry System for the oceanographic monitoring will distribute data in two ways:

- Local distribution - direct radio communication between the buoy and MSP
- Global distribution - data will be transmitted via Argos transmitter to the Argos satellite

The oceanographic buoy will have measurement sensors for conductivity, oxygen, temperature, pressure (depth), turbidity, current (Acoustic Doppler Current Profiler), wave/tide, air pressure, wind speed, air temperature, humidity and solar irradiance.

At MSP there will be configuration for data collection and backup (1 PC with appurtenant software), which will allow:

- Database elaboration and maintenance
- Graphical applications (plots of data)
- Numerical applications (spectrum calculations, data filtering)
- Data exchange with WEB server
- Design and presentation of data products on the WEB
- Internet communications tool (FTP, telnet)

From MSP the data and data products would be broadcast via WEB server. Data products will be composed of time series of previous 24 hours, basic statistics (daily averages and trends) and meta-data (information about the data and sensors).

The COSP and two buoys on the Italian side will measure the time series of parameters (temperature, salinity, chlorophyll etc.). Through research vessel surveying we will obtain also the spatial distribution of the parameters. These surveys will be also triggered off by some peculiar behaviour of certain quantity, which would be noticed from the time series of data received from COSP, such as concentration of dissolved oxygen or low surface salinity (riverine freshwater spreading also in the southern part of the Gulf of Trieste). We expect to obtain a new research vessel by the end of 1999.

The announcement of tenders has already been launched. It is expected that COSP will start to operate before June 2000. When operating, the MedGOOS secretary will be notified and the arrangements for invoking the MedGOOS in the net of operational oceanography will commence.

Among others, the mission of COSP will be to obtain the data significant for the study of known phenomena, e.g. flooding and anoxia.

Flooding in northern Adriatic does not occur only in Venice but also in towns on the eastern coast, such as Piran. The flooding is interplay between high tides and interaction with the storm-surge. The latter is driven by

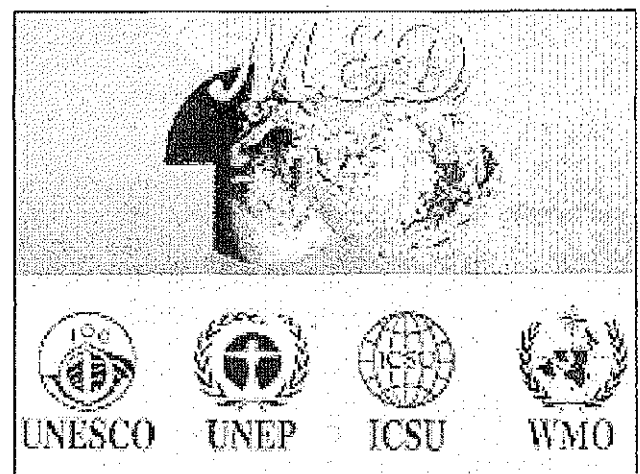
atmospheric pressure gradients as well as by the wind field. COSP will measure wind field at one spot above the sea - these are the "missing data" for the evaluation of the storm-surge. Wind driven circulation has not been modelled yet with "in situ" observations simply because there are NO data at the sea. The wind field, which is estimated from the coastal stations that are behind or in front of topographic abruption (Trieste), is far from the real situation at sea.

The Gulf of Trieste, a semi-enclosed shallow area with depths of less than 30 m, is one of those coastal regions that show varying degrees of oxygen impoverishment at the depths greater than 20 m. The oxygen depletion is the consequence of consumption of oxygen at the bottom and too low input of oxygen from the upper part of the water column. Severely hypoxic/anoxic bottom waters lead to benthic mortalities. Anoxia takes place in September and October when the dynamics of water mass is weak and pycnocline is present near the bottom.

With a vertical profiling system we intend to gain a better view into the bottom layer anoxia/hypoxia and to relate it to the horizontal movement of water mass to stratification and, unhelpfully, also monitoring of oxygen consumption (benthic chambers) near the ocean buoy - also located in place where hypoxia has been noticed.

Similar project (oceanographic buoy on the Italian side) was also presented by Roberto Purini from ITS-CNR Trieste, Italy.

At the Workshop, the EU programs for the Mediterranean and operational oceanography were also presented. The working groups were formed for actions to start the implementation of MedGOOS.





Sonja Škornik

POROČILO O SIMPOZIJU "FLORA IN VEGETACIJA SLOVENIJE 1999".

Gozdarski inštitut Slovenije, Ljubljana,  
26. in 27. 11. 1999

V dneh 26. in 27. novembra 1999 je na Gozdarskem inštitutu v Ljubljani potekal 3. simpozij Flora in vegetacija Slovenije. Poleg slovenskih botanikov so se ga udeležili tudi gostje iz Hrvaške in Avstrije. Simpozij je pripravilo Botanično društvo Slovenije pod pokroviteljstvom Ministrstva za znanost in tehnologijo, posvečeno pa je bilo spominu na 100. obletnico rojstva prvega slovenskega fitocenologa Gabrijela Tomažiča.

Vsebinsko je srečanje zajelo naslednje tematske sklope: fitocenologijo, sistematiko, floristiko in drugo, predvsem v povezavi z delovanjem G. Tomažiča. Prispevki so bili predstavljeni v obliki predavanj in posterjev, izvlečki pa so zbrani v Zborniku izvlečkov referatov simpozija, ki ga je uredil N. Jogan.

Po uvodnih pozdravnih besedah predsednice Botaničnega društva Slovenije M. Škornik sta zbrane nagovorila tudi minister za znanost in tehnologijo Republike Slovenije dr. L. Marinc̄ek in direktor Gozdarskega inštituta Slovenije N. Torelli.

Sledila so uvodna plenarna predavanja, posvečena predstavitvi življenja in dela G. Tomažiča. Njegovo življenjsko pot je v svojem prispevku natančno orisal dr. T. Wraber. Njegova dela in s tem tudi zgodovino raziskovanja tako gozdne kot traviščne vegetacije v Sloveniji pa so predstavili D. Robič, M. Zupančič in I. Trinajstič. Pred zaključkom dopoldanskega dela sta sledili še predavanja, ki sta posegli na malce drugačni področji. Gost iz Avstrije, H. Mayrhofer (s soavtorji) je predstavil rezultate večletne raziskave biodiverzitete lišajev v Sloveniji, ki jo opravljajo strokovnjaki Univerze v Ljubljani in Gradcu. N. Torelli pa je govoril o pojavih abszcizije v lesu.

Popoldanski del prvega dne je bil namenjen referatom s področja fitocenologije. Fitocenološko problematiko gozdne vegetacije so obravnavali M. Acceto, Ž. Košir in P. Košir (s soavtorji). B. Čušin je predstavil novo subasociacijo s prodišč reke Nadiže, T. Wraber pa petrofilno vegetacijo Snežnika. I. Daskobler je podal fitocenološko oznako rastišč naše endemične vrste *Moehringia villosa*. Vegetacijo travišč v Sloveniji sta v svojih prispevkih obravnavala S. Škornik in A. Seliškar, A. Martinčič pa je prikazal vegetacijsko podobo vrste *Shoenus ferrugineus*. Prvi dan simpozija je z referatom o novostih v poznavanju halofitne vegetacije na slovenski obali zaključil M. Kaligarič.

Drugi dan so bili najprej predstavljeni referati s področja sistematike. Gostja s Hrvaške B. Mitić (s soavtorji) je poročala o izsledkih morfoloških in karioloških analizah vrste *Iris cengiatti* v Sloveniji. N. Jogan

in B. Frajman pa sta posegla v problematiko skupin *Hordeum murinum* agg. in *Dryopteris carthusianorum* agg. F. Batič (s sodelavci) je predstavil način ugotavljanja križancev hrastov doba in gradna z morfološko analizo listov.

Sledila je sekcija, kjer so avtorji predstavljali svoje posterje. Ti so s svojo tematiko posegali na različna področja delovanja, med avtorji pa je bilo vzpodbudno veliko mladih raziskovalcev. L. Atanasova (s soavtorji), T. Bačič, B. Trčak, J. Plazar in S. Strgulc so obravnavali problematiko različnih taksonov v Sloveniji. B. Rozman je predstavil bogastvo flore Rovt v osrednji Sloveniji, C. Battellija pa je prikazal nove vrste alg slovenskega morja. Vegetacijo različnih predelov Slovenije so preučevali T. Horvat (s soavtorji) L. Kutnar, V. Petrinc in U. Šilc. Bioklimo v Sloveniji je predstavil M. Jarnjak (s soavtorji). I. Zelnik (s soavtorji) pa je predstavil ekološko in vegetacijsko problematiko ozelenitve in stabilizacije obcestnih brežin. S posterjem so sodelovali tudi kolegi z Univerze na Dunaju, ki so nas seznanili z novim računalniškim programom za pomoč pri obdelavi vegetacijskih podatkov.

V popoldanskem in hkrati zaključnem delu je sledilo še nekaj referatov. N. Jogan (soavtor M. Kotarac) je predstavil novo bazo podatkov, za izdelavo katere je rabila Hayekova flora. B. Vreš je posegel v taksonomsko problematiko rodu kislic v Sloveniji. J. Bavcon pa je govoril o pomenu botaničnih vrtov kot nadomestnih rastišč za ogrožene rastlinske vrste. H. Kraigher je predstavila metode kartiranja tipov mikorize. O parožnicah - skupinah zelenih alg - v Sloveniji je poročala O. Urbanc-Berčič. Simpozij je zaključila M. Škornik s predstavitvijo G. Tomažiča kot pisca srednješolskih učbenikov.

Vesna Flander Putrlj

ADVANCED STUDY COURSE ON THE  
MEDITERRANEAN MARINE SYSTEM  
(4-17 July 1999 in Barcelona, Spain)

The advanced study courses in the field of marine science and technology are part of the training programme developed within MAST (Marine Science and Technology Programme of the European Union) and they relate to the core topics of the MAST Programme. The main objectives of the study courses are to further advance education of topics at the forefront of scientific and technological development at the European level. I was selected among more than 130 applicants to participate in one of them: MAST Advanced Study Course on the Mediterranean Marine System which took place in Barcelona, Spain from 4<sup>th</sup> to 17<sup>th</sup> July 1999. The

course was intended for a maximum of 30 PhD students and young scientists interested in a multidisciplinary view of the Mediterranean Sea. The course was also open to students from non-EU, non-EEA/EFTA countries.

The Mediterranean Sea is a unique feature of the world ocean, located in the latitudinal fringe separating the arid North African region from the more humid, mid latitude lands of Europe. The Mediterranean Basin is made of various sub-basins showing contrasting characteristics and connected through straits. Exchanges with the open ocean are limited to the Strait of Gibraltar. Horizontal and vertical gradients are of fundamental interest in the dominantly oligotrophic Mediterranean Sea. Marked gradients exist from west to east across the entire basin and at mesoscale dimension. The seasonal imprint on natural processes is of paramount importance in the Mediterranean Sea, with short-lived events playing a fundamental role. Also, strong hiperannual changes could lead to the formation of deep water during winter times, or prevent such a formation of deep waters, a phenomenon that has a profound influence on the ventilation of the deep benthic domain.

Heavy industrial, agricultural and urban discharges from its watershed have an important impact on the health and chemistry of the Mediterranean Sea. Increased use of water from irrigation, industrial and urban purposes, and for hydroelectricity generation, is enhancing the hydric deficit of the Mediterranean Sea and is probably modifying the properties of the water masses.

The aim of this course was to provide the participants with a coherent overview of the present knowledge of the Mediterranean Sea System, where substantial progresses have been achieved during the last six years mainly through the EU funded, integrated, multiscale Mediterranean Targeted Project (1993-99). The course had a comprehensive scope and covered a large range of disciplines. Lectures and practical exercises were organised in four thematic blocks: 1) Deep water formation, circulation (ocean and atmosphere) and its

modelling; 2) Primary production, biogeochemical fluxes and benthic response; 3) The sediment record of past environments and events; 4) Lessons from outside the Mediterranean Sea. Lecturers were prominent scientists from both European and non-European countries strongly involved in Mediterranean Sea research and with an excellent reputation in their field. The course itself represented a unique and timely opportunity to learn about the ultimate findings on the Mediterranean Sea System.

The option to participate in specific legs of the Transmediterranean Research Cruise onboard R/V Aegeo, during the month of June 1999, was offered to the students. The cruise started in Piraeus (Greece) and ended in Barcelona (Spain), giving the students a unique opportunity to acquire research experience and to work together at sea with the lecturers of the course. I was appointed for the last leg of this cruise; my embarkment place was Maho in Menorca (Spain) and I disembarked in Barcelona (Spain). During the research cruise we sampled at one of the sampling stations in the Mediterranean Sea, at a depth of 2500 m. We have done the CTD-Rosette, measurements of primary production, zooplankton net deployment (transect), multicorer and gravity corer. Those are the different sampling techniques in the sea.

The organisers of the course took very good care of us in Barcelona. They organised a visit of "Aquarium de Barcelona" which contains 20 large individual tanks and a spectacular Oceanarium with a transparent underwater tunnel more than 80 metres long. You may also enjoy with Miniaquaria, a new concept of L'Aquarium to see all the finest details of Mediterranean flora and fauna totally overlooked in large aquariums. And at the end we also had a "Tasting of Spanish wines excursion".

The course and the cruise was very well organized and it was a very nice experience for me to spend the time with people interested in the same thing as I am - the Mediterranean Sea.

OCENE IN POROČILA  
RECENSIONI E RELAZIONI  
REVIEWS AND REPORTS

James Higginbotham: PISCINAE. ARTIFICIAL FISHPONDS IN ROMAN ITALY. University of North Carolina Press: Chapel Hill and London, 1997 (1998); 284 strani.

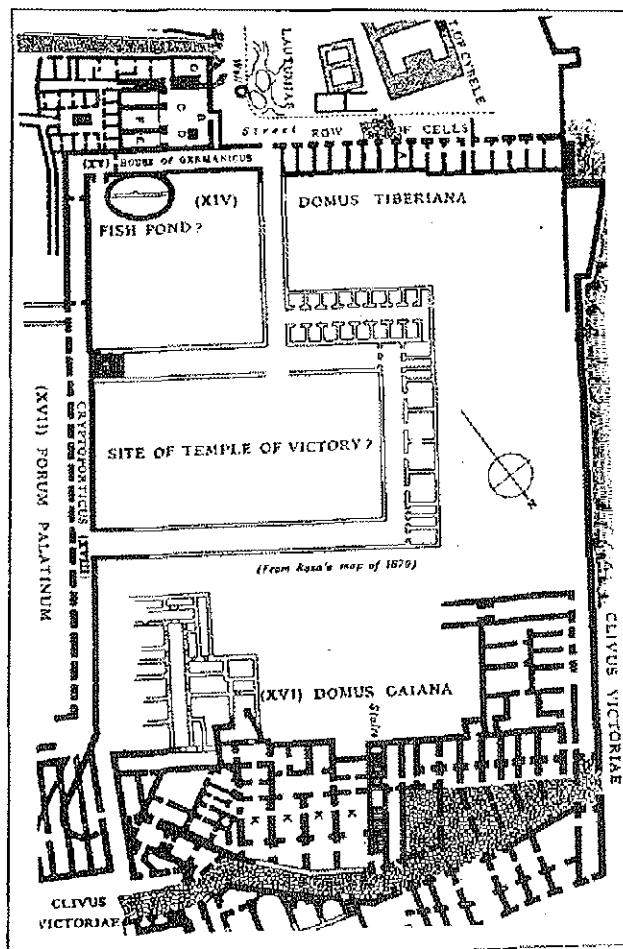
Pri založbi Univerze Severne Karoline je izšlo delo J. Higginbothama o ribnikih v rimski Italiji. Delo na poseben način združuje pregled literarnih in arheoloških virov o umetnih ribnikih, ki so poleg tehnološke dovršenosti tudi dokument o socialni strukturiranosti družbe, posebej visjih slojev, ki so si takšne instalacije hoteli in mogli privoščiti.

Do sedaj so se z obmorskimi ribniki intenzivno ukvarjali intenzivno predvsem geologi in geografi, seveda zaradi vidnih sledov naraščanja morske gladine v času od zgraditve ribogojnic pa vse do danes (Euzennat, 1987; Šegota & Filipčić, 1991).

V začetnih poglavjih avtor razčlenjuje literarne vire, ki odslkavajo stanje v časovnem okviru pozne republike in zgodnjega cesarstva. Zlasti Columella stvarno opisuje stanje v 1. st., ko so bile razmere že precej drugačne kot ob koncu republike. Jedro knjige predstavlja primerjava literarnih virov z arheološkimi ostanki ter katalog (nad 50) ribnikov.

V naslovu je sicer omenjena *rimška Italija*, vendar se avtor se omejuje, kar mu lahko nekoliko očitamo, predvsem na tirensko obalo, nekako med Elbo na severu in Paestumom na jugu; izjema bi bil le ribnik iz "Castrum Novum" na vzhodni obali polotoka (zemljevid na str. 70/71), ki pa ga avtor v tekstu ne obravnava. Osredotoči se tudi predvsem na objekte, ki dajejo kar največ možnosti za študij vloge ribnikov in njihovih konstrukcijskih značilnosti. Toda s podrobnim kritičnim pregledom virov in predvsem poročil o izkopavanjih bi bilo moč zaslediti še kakšen ribnik, še posebej zunaj omenjenega področja, kakor je to nakazal že X. Lafon (1998) v prikazu Higginbothamovega dela. Vsaj delno je v obravnavanem času med italske regije navsezadnje sodila tudi Istra in morda bi bilo treba omeniti domnevne ribnike z Brionov-Brijunov (Matijašič, 1998), morda pa tudi domnevni ribnik ob Debelem rtiču (Župančič, 1989/90); poleg teh vsekakor vsaj še nekaj najdišč: Čedas, (kjer so bazeni morda v 1. stoletju rabili tudi za izdelavo garuma: Fontana, 1993), Šipar - čeprav nejasno (Degrassi, 1957 Kozličić, 1987), Sv. Andrej-Medulin časovno neopredeljen (Matijašič, 1994), Barbariga-Sv. Jakob s časovno neopredeljenim bazenom (Matijašič, 1994).

Druga avtorjeva omejitev je časovna, saj je obravnaval le zadnje stoletje pred našim štejetjem in prvo po njem. Najstarejše instalacije so izvedene v opus incertum, po



Ovalni ribnik (11,8 x 8 m<sup>2</sup>) v Tiberijevi palači v Rimu. Odkrit je bil že med izkopavanji, ki jih je po letu 1860 vodili na zahtevo francoskega cesarja Napoleona III. Stene so bile iz rimskega cementa iz vulkanskega pepela. Po dolgi osi poteka poglobljen kanal, ki omogoča sedimentacijo, stopenjska struktura pa lahek dostop pri vzdrževanju ribnika. Ribnik je bil v starejši palači zgrajen v drugi polovici prvega stoletja po našem štejetju (po Higginbotham 1997, sl. 37).

Domus Tiberiana in Rome, plan of the palace with the oval fishpond, known since it was uncovered during the excavations at the behest of the French emperor Napoleon III after 1860. Along the long axis of the pond runs a channel for sedimentation of detritus; the two-step structure permitted the access during the cleaning of pond. The construction of the fishpond is dated in the second half of 1st cent. A.C (after Higginbotham 1997, fig. 37).

vsej verjetnosti ne prej kot ob koncu 2. st. pred našim štejetjem, pa tudi noben od naštetih obmorskih ribnikov ni izveden v opus latericium, v tehniki torej, ki je značilna za 2. in 3. stoletje. Prevladuje tehnika opus reticulatum, tako značilna za čas od sredine 1. st. pr. n. štejetjem do

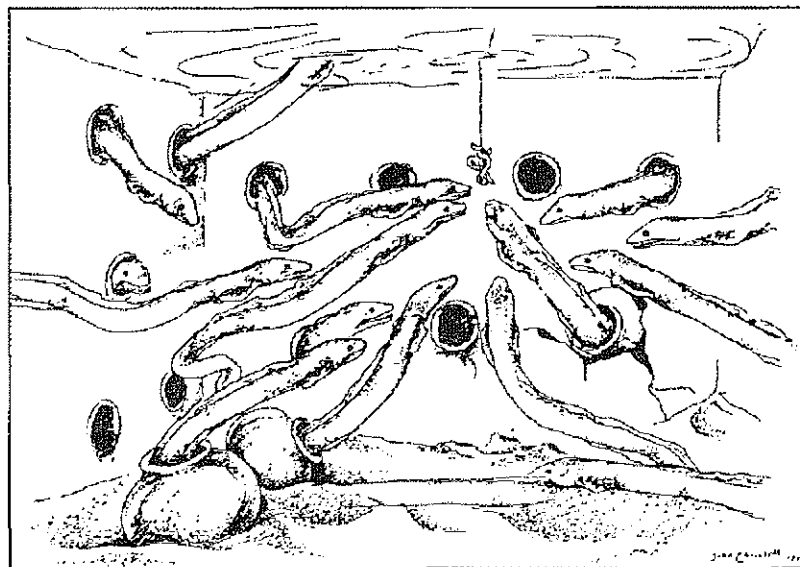
sredine prvega stoletja našega štetja. Razvoj ribnikov v notranjosti, ki se jim avtor manj posveča, na kar je opozoril tudi X. Lafon, je drugačen.

Ribogojstvo je samo po sebi dokaj zahteven posel, ki ne zahteva le dobrega izbora rib, marveč tudi ustvarjanje umetnih razmer za vzrejo. Nedvomno je bilo najlažje začeti gojiti ribe v lagunah, saj dajejo možnosti za preprosto zapiranje ribjih jat in ekstenziven pristop. Prehod h grajenim ribnikom se je ob tirenski obali dogodil v teku 2. st. pr. n. št., s tem pa hkrati k intenzivni gojitvi, torej h kontroliranemu dodajanju hrane ribam. Tako pisani kot arheološki viri kažejo, da so bili ti ribniki povezani z velikimi rimskimi vilami ob morski obali. Poleg ekonomskega pomena vzreje rib je treba upoštevati, vsaj pri najvišjem razredu in v njegovih arhitekturnih prizadevanjih, tudi z luksuznostjo in ambientalno vrednostjo ribnika v sklopu vile. Lahko prisluhnemo Ciceronu, ki pravi, da "nekateri piscinariji bolj cenijo svoje ribnike kot politično življenje".

Izbor vrst rib za gojenje, kot jih navaja avtor, kaže na prevlado takšnih, ki lahko vzdržijo dokajšen razpon slanosti vode, a vendarle na trgu veljajo za morske. To slednje je končno tudi ekonomska kategorija, saj je bilo meso morskih rib bolj cenjeno od sladkovodnih. Ko obravnava ribe, ki bi bile primerne za gojitev, avtor seveda naleti na težave pri poimenovanju posameznih rib. Pa vendar s pritegnitvijo pisanih in slikanih virov lahko z dokajšnjo gotovostjo ugotovi kriterije, ki so

Rimljane vodili pri izboru rib: *murenae*, *mugiles*, *lupus*, *auratae*, *mullidae*, *rhombi*, *scaridae*. Naštete oznake rib tu pa tam odsevajo zadrego, v kateri se je znašel avtor, ko jih je želel opredeliti na osnovi dvoumne taksonomije tedanjega časa in našega<sup>1</sup> (še) skromnega poznavanja stvarnih ostankov kosti in lusk. Tako se pod oznako *murenae* skrivajo ne le murene, pač pa tudi ugorji in jegulje, v manjši meri pa celo piškurji. Oznaka *mugiles* (ciplji) velja kar za štiri vrste cipljev, medtem ko z *lupi* iz družine ustnač (Labridae) avtor po vsej verjetnosti označuje brancina (*Morone labrax*). Naštevata tudi *auratae*, to je orado (*Sparus aurata*); z oznako *mulli* (bradač oziroma trilje, barboni) opisuje dve vrsti, katerih ena živi na mulju (*Mullus barbatus*), druga pa na kamnitem svetu (*Mullus surmulatus*). Z oznako *rhombi* avtor omenja ribe iz skupine bokoplavutaric (hrv. "rombi" ali "robci"), a k njim prišteva tudi, logično, morske liste (it. "solea") in morski jezik ("citharus"). Pod izrazom *scari - scaridae* poznamo danes v vzhodnem Sredozemlju le eno vrsto *Sparisoma cretense*, kakor poročata že Plinij in Collumella. Očitno je gojenje v Italiji te - kdaj pa kdaj prestižne - uvažane ribe povzročalo težave. Omenjene so še nekatere ribe, n.pr. *acipenser* (jeseter), *asellus* (oslič - *Merluccius merluccius*) in *scomber* (skuša - *Scomber scomber*, *S. japonicus*).

Avtor se manj ukvarja z ribniki iz notranjosti s sladko vodo. Graditev velikih akveduktov je omogočila tudi tam, nekako od Avgustovega časa naprej, nastanek več-



Sodobna risarska upodobitev (J. Christoff) rimskega zidanega ribnika za jegulje. V stenah so vidne vgrajene lončene posode, ki nudijo ribam primerna zatočišča (Higginbotham 1997, sl. 3).

Eels in a fishpond equipped with wall recesses made from ceramic vessels, recent drawing by J. Christoff (Higginbotham 1997, sl. 3).

1 Predvsem zaradi mojega nepoznavanja taksonomije mi je v naslednjih vrsticah priskočil na pomoč dr. Lovrenc Lipej. Dolgujem mu zahvalo!

jega števila ribnikov. Izkazalo pa se je, da med gojenimi zvrstmi prevladujejo takšne, ki lahko živijo tudi v manj slani in celo sladki vodi, na primer jegulje.

Avtor prikazuje tudi tehnične podrobnosti ribnikov, izvedbo sten in zaščito rib pred soncem, dotok sveže vode in položaj ribnikov v sklopu luksuzne vile. Nakazane tehnične lastnosti ribnikov, gojenje rib v lagunah in izlivih rek ter vrste rib, ki so jih po Higginbothamu gojili Rimljani, nam naposled omogočajo pripravo novih izhodišč pri iskanju morebitnih sledov ribogojstva od rimskega časa naprej tudi v obrežnem področju istrske Slovenije. Le škoda je, da v naših obmorskih mestih in njihovih akvatorijih še niso bili lokalizirani niti srednjeveški ribniki, omenjeni v listinah, in redko celo z ohranjenim toponimom.

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**Matej Župančič**

#### ECOSYSTEMS AT THE LAND-SEA MARGIN - DRAINAGE BASIN TO COASTAL SEA

Eds: T. C. Malone, A. Malej, L. W. Harding, N. Smodlaka & R. E. Turner.

Coastal and estuarine studies 55, American Geophysical Union, Washington, 1999, 381 str.

Pred leti smo v Annales poročali o mednarodni delavnici z nenavadnim naslovom: "Trends in Land Use, Water Quality and Fisheries: A comparison of the

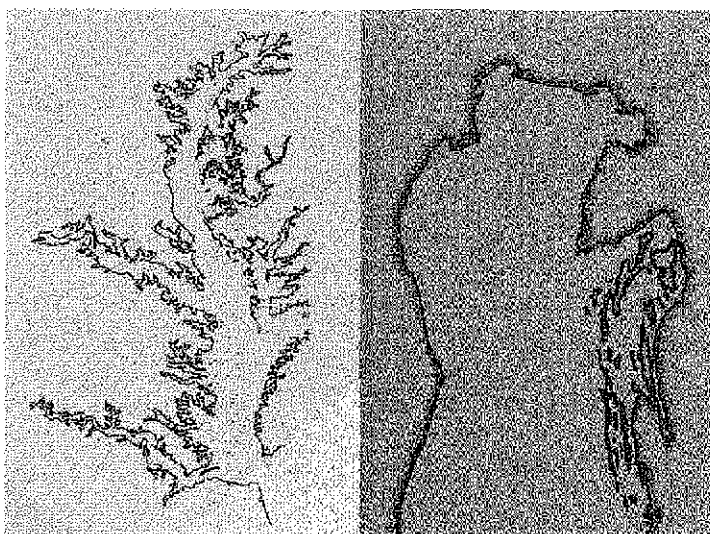
Northern Adriatic and the Chesapeake Bay" (A. Malej; Annales 7'95:265-266). Delavnice, ki je nastala v okviru sodelovanja med ZDA ter Slovenijo in Hrvaško, se je v obdobju od 14. do 20. maja 1995 udeležilo okoli 40 vodilnih strokovnjakov z različnih področij morskih znanosti iz Slovenije, Hrvaške, Italije, Avstrije in ZDA. Poročevalka je tedaj omenjala tudi tiskanje knjige, ki je z manjšo zamudo letos tudi izšla. Knjigo je izdala ameriška geofizikalna zveza (American Geophysical Union), uredili pa so jo T. C. Malone (ZDA), A. Malej (Slovenija), L. W. Harding (ZDA), N. Smodlaka (Hrvaška) in R. E. Turner (ZDA). Izhodiščna tema knjige je primerjalna analiza vplivov obogatitve s hranilnimi snovmi (ki se spirajo iz zbirnega območja v reke in naknadno) v dveh relativno zaprtih morjih. Knjiga ima 381 strani in je opremljena s številnimi diagrami, ilustracijami in preglednicami. Obsega 12 zaključenih poglavij, pri pripravi katerih je sodelovalo 35 avtorjev iz petih, zgoraj omenjenih držav. Vsako poglavje je nekakšna primerjalna sinteza poznavanja dane tematike na območju zaliva Chesapeake in severnega Jadrana. Po kratkem uvodnem poglavju, v katerem uredniki predstavijo obe obravnavani območji, sledijo poglavja o viru hranil in njihovem vnosu v obalno morje, spremembah habitatov v obalnem prostoru, procesih kroženja vode v obeh morjih, letnih ciklih in večletnih spremembah v produkciji fitoplanktona, cvetenju oklepnihih bičkarjev in pojavu "sluzastega morja", pomenu mikrozooplanktona v prehranjevalnem spletu, možnih povezavah med meduzami in evtrofikacijo ter ribištvom, povezavah med makrobentoškimi združbami in ribištvom, povezavah med procesi v vodnem stolpcu in na dnu ter kroženjem hranilnih snovi in o trendih v populacijah in izlovu rib ter upravljanju. V zaključnem poglavju uredniki povzamejo ugotovitve iz vseh predhodnih poglavij in kritično razpravljajo o pomanjkanju znanja na nekaterih področjih raziskav.

Avtorji so knjigo posvetili dr. Noellii Revelante, nedavno preminuli priznani planktologinji in pionirki na področju raziskav mikrozooplanktona, ki je kot avtorica enega od poglavij tudi sodelovala v pripravi knjige.

Knjiga je namenjena predvsem strokovnjakom iz različnih naravoslovnih ved, ki se ukvarjajo z raziskovanjem morja, primerna pa je tudi za študente. Njena vrednost se kaže tudi v tem, da je v posameznih poglavjih zbrano današnje vedenje o danem problemu na območju severnega Jadrana. Avtorjem ni kaj dosti očitati; pripravili so odlično knjigo o vplivih obogatitve z nutrienti, v kateri so sodelovali najboljši strokovnjaki iz ZDA in Evrope. Če že moram kaj pokarati, potem je to nekvadratno slikovno gradivo, ki so ga prispevali praviloma evropski avtorji v nekaterih poglavjih, in pogosto pomanjkanje pravih sumnikov v citatih, pa tudi v besedilu. V nekaterih poglavjih so sodelovali nekateri slovenski avtorji, ki so gotovo na svojem področju priznani, vendar so bili pri pisanju včasih zelo nerodni.

# COASTAL AND ESTUARINE S T U D I E S

## Ecosystems at the Land-Sea Margin Drainage Basin to Coastal Sea



Thomas C. Malone, Alenka Malej,  
Lawrence W. Harding, Jr., Nenad Smodlaka,  
and R. Eugene Turner, Editors

American Geophysical Union

Tako npr. Marušič (čeprav so v naslovu poglavja napisali Marusič, pa tudi italijanskemu kolegu so dodali en *i* preveč - Cecconii), ki je soavtor poglavja o spremembah habitatov v obalnem prostoru, citira Škornika, koprškega ornitologa (strokovnjaka za ptice), kadar piše o izsuševanju koprške bonifike v letih 1932-1939, Križana (geografa) pa ko piše o številu ptic, ki gnezdiijo in prezimujejo (tu gre za napačen podatek o 200 vrstah, ki prezimujejo) v Sečoveljskih solinah, o katerih med drugim pravi, da imajo zelo negotovo usodo zaradi morebitnega širjenja letališča in dirkališča. Vsekakor je

knjiga zelo kvalitetna, zato ji te napakice, ki so očitno posledica dejstva, da je urednikom zmanjkalo sape pri napornem medcelinskem urednikovanju, lahko zlahka oprostimo.

Z izdajo knjige so jadranski in ameriški naravoslovci iz raznih inštitutov za raziskovanje morja kronali uspešno zaključeno medcelinsko delavnico iz leta 1995. Informacije za nakup knjige lahko dobite na medmrežnem naslovu: <http://www.agu.org/pubs/agu-prt.html>.

Lovrenc Lipej

## NAVODILA AVTORJEM

1. **ANNALES**: *Anali za istrske in mediteranske studije* - *Annali di Studi istriani e mediterranei* - *Annals for Istran and Mediterranean Studies* (do 5. številke: *Anali Koprškega primorja in bližnjih pokrajin* - *Annali del Litorale capodistriano e delle regioni vicine* - *Annals of the Koper Littoral and Neighbouring Regions*) je znanstvena in strokovna interdisciplinarna revija humanističnih, družboslovnih in naravoslovnih vsebin v podnaslovu opredeljenega geografskega območja.

2. Sprejemamo prispevke v slovenskem, italijanskem, hrvaškem in angleškem jeziku. Uredništvo ima pravico prispevke jezikovno lektorirati.

3. Prispevki naj obsegajo največ 24 enostransko tipkanih strani s po 30 vrsticami. Na levi pustite 3 do 4 cm širok rob. Zazeljeno je tudi (originalno) slikovno gradivo, še posebno pa oddaja prispevka na računalniški disketi v programih za PC (osebne) računalnike.

4. Naslovna stran tipkopisa naj vsebuje naslov in podnaslov prispevka, ime in priimek avtorja, avtorjeve nazive in akademske naslove, ime in naslov institucije, kjer je zaposlen, oz. domači naslov vključno s pošto številko.

Uredništvo razvršča prispevke v naslednje **kategorije**:

*Izvirna znanstvena dela* vsebujejo izvirne rezultate lastnih raziskav, ki še niso bili objavljeni. Dela pošlje uredništvo v recenzijo. Avtor se obvezuje, da prispevka ne bo objavil drugje.

*Strokovna dela* prikazujejo rezultate strokovnih raziskav. Tudi te prispevke uredništvo pošlje v recenzijo in avtor se obveže, da prispevka ne bo objavil drugje.

*Pregledni članki* imajo značaj izvirmih del. To so natančni in kritični pregledi literature iz posameznih zanimivih strokovnih področij (review article).

*Gradiva* imajo ravno tako značaj izvirmih del.

*Poročila* vsebujejo krajše znanstvene informacije o zaključenih raziskovanjih ali kratek opis strokovnih in znanstvenih knjig ali srečanj. Taki prispevki ne smejo presežati 5 strani.

*Mladinske raziskovalne naloge* morajo biti urejene kot strokovna dela.

*Komentarji* so namenjeni aktualnostim s strokovnega področja. Ne smejo presežati 2 strani.

*Obvestila* so namenjena društvenemu življenju. Obsegajo 1 stran.

5. Prispevek mora vsebovati **povzetek** in **izvleček**. Izvleček je krajši (cca. 10 vrstic) od povzetka (cca. 30 vrstic) in v nasprotju s povzetkom tudi ne vsebuje komentarjev in priporočil.

V *izvlečku* na kratko opišemo namen, metode dela in rezultate. Navedemo, čemu smo delo opravili ali napisali dokument. Na že objavljeno gradivo se sklicujemo le, če je to glavni motiv dela. Na kratko opišemo metode in tehnike dela - kolikor je potrebno za razumevanje. Nove tehnike opišemo le, kjer se razlikujejo od že znanih. Če v delu ne opisujemo eksperimentalnega ali praktičnega dela, opišemo vire informacij. Rezultate in zaključke lahko združimo. Kar se da informativno navedemo le, kaj smo ugotovili oziroma odkrili.

*Povzetek* začnemo s stavkom, ki vsebuje glavno sporočilo dela. Stavki naj bodo popolni in ne predolgi. Pišemo v tretji osebi, le izjemoma uporabimo glagole v neosebni obliki. Uporabljamo pravilni strokovni jezik in se izogibamo slabše znanim kraticam. Ohraniti moramo osnovno informacijo in poudarke iz glavnega besedila. V povzetku ne sme biti ničesar, česar glavno besedilo ne vsebuje.

6. Avtorji so dolžni definirati in pripisati ustrezne **ključne besede** (pod izvlečkom) članka. Zazeljeni so tudi **angleški (ali slovenski) prevodi** ključnih besed, podnapisov k slikovnemu in tabelarnemu gradivu. Priporočamo se še za angleški (ali slovenski) prevod povzetka, sicer bo za to poskrbelo uredništvo.

7. V besedilu se po možnosti držimo naslednjih poglavij:

1. Uvod.
2. Pregled dosedanjih objav.
3. Materiali in metode (Dokazni postopek).
4. Rezultati.
5. Razprava ali diskusija.
6. Zaključek (Sklepi).
7. Zahvala - če avtor želi.
8. Priloge - če je potrebno.
9. Literatura (Viri, Bibliografija).
10. Povzetek (Summary).
11. Izvleček.
12. Ključne besede (neobvezno).

8. Ločimo **vsebinske** in **bibliografske opombe**. Vsebinske opombe besedilo še podrobneje razlagajo ali pojasnjujejo, postavimo jih *pod črto*. Z bibliografsko opombo pa mislimo na citat - torej sklicevanje na točno določeni del besedila iz neke druge publikacije (navedemo tudi točno stran, kjer je citat objavljen) ali na publikacijo (članek) kot celoto (točne strani, kjer smo besedilo prevzeli, ne navajamo).

Bibliografsko opombo sestavljajo naslednji podatki:

Avtor, leto izida in - le če citiramo točno določeni del besedila - tudi navedba strani.

Celotni bibliografski podatki citiranih in uporabljenih virov so navedeni v poglavju *Literatura* (Viri, Bibliografija).



Primer citata med besedilom:

(Grafenauer, 1993, 11).

Primer navajanja vira kot celote, brez citiranja: (Grafenauer, 1993).

Popolni podatki o tem viru v poglavju Literatura pa se glasijo:

Grafenauer, B. (1993): Miti o "Istri" in resnica istrskega polotoka. V: Acta Histriae I. Koper, Zgodovinsko društvo za južno Primorsko, 9-52.

Če citiramo več del istega avtorja iz istega leta, poleg priimka in kratice imena napišemo še črke po abecednem vrstnem redu, tako da se viri med seboj razlikujejo. Primer:

(Grafenauer, 1993a); (Grafenauer, 1993b).

Bibliografska opomba je lahko tudi del vsebinske opombe in jo zapisujemo na enak način.

Posamezna dela ali navedbe virov v isti opombi ločimo s podpičjem. Primer:

(Gombač, 1996; Grafenauer, 1993b).

9. Pri citiranju arhivskih virov navedemo najprej arhiv, nato ime fonda ali zbirke in signaturo. V članku navajamo kratico arhivskega vira v oklepaju med besedilom. Kratico pa razložimo v poglavju o virih na koncu prispevka.

Primer navajanja arhivskega vira v oklepaju med besedilom: (PAK. RAG, 1)

Primer navajanja arhivskega vira v poglavju o virih: PAK. RAG - Pokrajinski arhiv Koper, Rodbinski arhiv Gravisi, a. e. (arhivska enota) 1.

Podobno poskušamo ravnati pri uporabi časopisnih virov.

10. Poglavje o literaturi in virih je obvezno. Bibliografske podatke navajamo takole:

- Opis zaključene publikacije kot celote - knjige:

Avtor (leto izida): Naslov. Zbirka. Kraj, Založba. Npr.:

Verginella, M., Volk, A., Colja, K. (1995): Ljudje v vojni. Druga svetovna vojna v Trstu in na Primorskem. Knjižnica Annales 9. Koper, Zgodovinsko društvo za južno Primorsko.

V zgornjem primeru, kjer je avtorjev več kot dva, je korekten tudi citat:

(Verginella et al., 1995)

Če navajamo določeni del iz zaključene publikacije, zgornjemu opisu dodamo še številke strani, od koder smo navedbo prevzeli.

- Opis prispevka v zaključeni publikaciji - npr. prispevka v zborniku:

Avtor (leto izida): Naslov prispevka. V: Avtor knjige: Naslov knjige. Izdaja. Kraj, Založba, strani od-do. Primer:

Verginella, M. (1995): Poraženi zmagovalci. Slovenska pričevanja o osvobodilnem gibanju na Tržaškem. V: Verginella, M. et al.: Ljudje v vojni. Druga svetovna vojna v Trstu in na Primorskem. Knjižnica Annales 9. Koper, Zgodovinsko društvo za južno Primorsko, 13-51.

- Opis članka v reviji:

Avtor (leto izida): Naslov članka. Naslov revije, številka. Kraj, Založba, strani od-do. Primer:

Gombač, B. (1996): Osvoboditev Trsta maja 1945. Annales 8/96. Koper, Zgodovinsko društvo za južno Primorsko - Znanstveno-raziskovalno središče Republike Slovenije Koper, 141-150.

Članki so razvrščeni po abecednem redu priimkov avtorjev ter po letu izdaje, v primeru da gre za več citatov istega-istih avtorjev.

11. Tiskarski znaki za poudarke naj bodo:

podčrtano za polkrepko,

valovito podčrtano za ležeče.

Računalniški zapis naj vključuje ustrezne oznake za bold in italics.

12. Kratice v besedilu moramo razrešiti v oklepaju, ko se prvič pojavijo. Članku lahko dodamo tudi seznam uporabljenih kratic.

13. Pri ocenah publikacij navedemo v naslovu prispevka avtorja publikacije, naslov, kraj, založbo, leto izida in število strani (oziroma ustrezen opis iz točke 10).

14. Prvi odtis prispevkov uredništvo pošlje avtorjem v korekturo. Avtorji so dolžni popravljeno gradivo vrniti v treh (3) dneh. Besedilo popravljamo s korekturnimi znamenji, ki jih najdemo na koncu Slovenskega pravopisa (1962), Ljubljana, ali v: Slovenski pravopis 1. Pravila (1990). Ljubljana, SAZU-DZS, 13-14.

Širjenje obsega besedila ob korekturah ni dovoljeno. Druge korekture opravi uredništvo.

15. Uredništvo prosi avtorje, naj navodila vedno upoštevajo. Ob vseh nejasnostih je uredništvo na voljo za vsa pojasnila.

UREDNIŠTVO

## INSTRUCTIONS TO AUTHORS

1. **ANNALES**; *Annals for Istran and Mediterranean Studies - Anali za istrske in mediteranske študije* (up to No. 5: *Annals of the Koper Littoral and Neighbouring Regions - Anali Koprškega primorja in bližnjih pokrajin*) is a scientific and research interdisciplinary review covering the humanities, sociology and natural science in the area as stated in the review's subtitle.

2. Articles (papers) written in Slovene, Italian, Croatian and English languages will be accepted. The Editorial Board reserves the right to have them linguistically revised and corrected.

3. Articles should be written on max. 24 pages with double spacing and on one side of the sheet only. On the left side of each page, a 3-4 cm wide margin is to be left. Original photographs, drawings and tables are welcomed, as well as diskettes containing the texts, together with reference to the programme used.

4. Title page of typescript is to include title and subtitle of the article (paper), author's name, any (academic) titles and name of institution by which employed or personal address.

Articles are arranged in the following eight **categories**:

*Original scientific works* containing not yet published results of the author's own research. Such works will be reviewed by scientists chosen by the Editorial Board. Authors oblige themselves not to offer their material to any other journal or magazine.

*Research works* presenting results obtained through research. They too will be reviewed, and authors oblige themselves not to publish them elsewhere.

*Review articles* bearing the character of original works. These are critical and detailed reviews of literature from various interesting fields of research.

*Materials and sources* also bearing the character of original works.

*Reports* include short scientific information on integral research work or a short description of scientific or specialist books or meetings of experts. Such articles are not to exceed 5 pages.

*Youth research compositions* are to be presented in the same way as research works.

*Explanatory comments* include topical issues from various fields of research and are not to exceed 2 pages.

*Notices* include news from various associations and should not exceed 1 page.

5. Articles should include both **summary** and **abstract**.

*Abstract* is the shorter of the two (with up to 10 lines) and does not include, in contrast to *summary* (with up to 30 lines), explanatory comments and recommendations.

*Abstract* is to contain a short description of the pur-

pose and methods of the work and its results. Author should also state why the work has been carried out and why a document has been written about it. References to the already published material are made only if this is the main purpose of the work. *Methods*: if necessary, work methods and techniques are to be briefly described (new techniques are to be stated only if differing from the already known ones). If no experimental or practical work is described, sources of information are to be given. Results and conclusions may be incorporated. Findings are to be presented as briefly as possible.

At the beginning of *summary* the essential points of the carried out work are to be presented. Sentences should be concise and not too long. The text is to be written in the third person; verbs may be used in impersonal form only exceptionally. The not so well known abbreviations are to be avoided. *Summary* is to retain the basic information from the main part of the text, and should not contain anything that does not appear in the main text itself.

6. Authors are obliged to define and state **key words** (below abstract) in their articles. **English (or Slovene) translation** of key words, texts accompanying figures and tables are welcomed, as well as English (or Slovene) translation of abstracts; if this is not convenient, the Board of Editors will provide for it.

7. Texts should include, if at all possible, the following chapters:

1. Introduction
2. Works published to date
3. Material and methods
4. Results
5. Discussion
6. Conclusions
7. Acknowledgements (if desired by author)
8. Supplements (if necessary)
9. References (Sources, Bibliography)
10. Summary
11. Abstract
12. Key words

8. Two kinds of *notes* are distinguished: those regarding the **contents** of the text, and those referring to **bibliography**. The first elucidate the text in even greater detail and are to appear *at the bottom of the page (under line)*. Bibliographical notes, which are to appear in brackets in the text itself, deal with quotations and refer to a precisely stipulated part of the text from some other publication (the page on which quotation appears is to be therefore stated as well) or to a publication (article) as a whole (in this case no page from which the text has been taken is to be stated).

Bibliographical notes are made up of the following details:

Author, year of its publication, and page (but only if a

precisely stipulated part of the text is quoted).

The entire bibliographical data of the quoted and used sources are to be stated under *References* (Sources, Bibliography).

Example of quotation referring to a precisely stipulated part of the text: (Sommerville, 1995, 11).

Example of source quotation as a whole, with no citation: (Sommerville, 1995).

The entire data of this source are to be stated in the references and sources chapter as follows:

**Sommerville, M. R. (1995):** Sex and Subjection. Attitudes to Women in Early-Modern Society. London-New York-Sydney-Auckland, Arnold.

If a number of works *by the same author from the same year* are quoted, letters in alphabetical order are to be stated apart from the author's surname and abbreviation of his first name, in order that the sources are clearly divided between each other. Example:

(Sommerville, 1986a); (Sommerville, 1986b).

Bibliographical note can also be a part of the note referring to the contents and is to be written in the same way, i.e. in brackets within the note referring to the contents.

Separate works or source quotations under the same note are to be separated with semicolon. Example: (Sommerville, 1986b; Caunce, 1994).

**9. When quoting archive sources,** the archive is to be stated first, then the name of the fund or collection and shelfmark. The abbreviation of archive source is to be stated in brackets in the text of the article. The abbreviation is to be explained in the references chapter at the end of the article.

Example of citing archive source in brackets in the text itself: (ASV. CSM, 240).

Example of citing archive source in the reference chapter: ASV. CSM - Archivio di Stato di Venezia. Cinque Savi alla Mercanzia, fasc. 240.

Review sources are to be stated in the same way.

**10. The references and sources chapter** is compulsory. Bibliographical data are to be stated as follows:

- Description of **integral publication:**

Author (year when published): Title. Volume - Collection. Place of publication, published by. Example:

**Caunce, S. (1994):** Oral History and the Local Historian. Approaches to local history. London and New York, Longman.

If there are *more than two authors*, the work can be also cited as:

(Matthews et al., 1990, 35)

If a specific part from an integral publication is quoted, the page numbers from which the quotation has been taken are to be added to the above description.

- Description of the **article (paper) in integral publication** - e.g. text in a collection of scientific papers: Author (year of its publication): Title of the paper. Author of the book: Title of the book. Volume - Collection. Place of publication, published by, pages from - to. Example:

**Matthews, R., Anderson, D., Chen, R. S., Webb, T. (1990):** Global Climate and the Origins of Agriculture. In: Newman, L. F. (ed.): Hunger in History. Food Shortage, Poverty, and Deprivation. Oxford-Cambridge, Blackwell, 27-55.

- Description of **article in certain review:** Author (year of its publication): Title of article. Name of review, its number. Place of publication, published by, pages from - to.

Example:

**Sluga, G. (1996):** Identity and Revolution: The History of the "Forty Days" of May 1945. *Annales* 8/96. Koper, Zgodovinsko društvo za južno Primorsko - Znanstveno-raziskovalno središče Republike Slovenije Koper, 125-140.

If the same author(s) is (are) cited a number of times, the articles are to appear in alphabetical order of the authors' surnames and year of publication.

**11. Printer's marks for accentuations** are to be as follows:

underlined for **semi-bold**,  
undulatory line for *italics*.

Computer notation is to include suitable marks for bold and *italics*.

**12. Abbreviations** in the texts are to be explained in brackets when appearing for the first time. A list of used abbreviations can be added to the article.

**13. When assessing a publication,** its author, title, place, publishing house, year of publication and page numbers (or appropriate description from Item 10) are to be stated in the title of the article.

**14. First copies of printed articles** will be sent to authors for **proof-reading**. Authors are obliged to return them in three (3) days. No new sentences are allowed to be added during proof-reading. The second (printing) proofs will be read by the Editorial Board.

**15. Authors** are kindly requested to consider these instructions at all times. In case of any indistinctness, please do not hesitate to contact the review's Editorial Board.

EDITORIAL BOARD

KAZALO K SLIKAM NA OVITKU

SLIKA NA NASLOVNICI: Oljka (*Olea europaea*) je značilno sredozemsko drevo, ki raste v Sloveniji na skrajnem robu svojega areala. (Foto: D. Podgornik)

1. Za sestoj žajblja (*Salvia officinalis*) in ruja (*Cotinus coggygria*) sta značilni visoka vrstna pestrost in gnezditvena gostota ptic. (Foto: D. Podgornik)
2. Zlata morska vetrnica (*Condylactis aurantiaca*) se krči in skriva v pesek. (Foto: T. Turk)
3. Goli pož *Crataena peregrina* se pase na trdoživnjaku. (Foto: T. Makovec)
4. Rak nagajivec (*Scyllarus arctus*) je manj znana vrsta dolgorepih rakov. (Foto: E. Spanier)
5. Oljčna vejica je po nekaterih izročilih simbol miru, modrosti in zmage. (Foto: D. Podgornik)
6. Oljčni nasad v Slovenski Istri. (Foto: D. Podgornik)
7. Južni podkovnjak (*Rhinolophus euryale*) z dobro vidno podkvasto obrazno masko je eden manj znanih vrst podkovnjakov v Sloveniji. (Foto: A. Hudoklin)
8. Veliki podkovnjak (*Rhinolophus ferrum-equinum*) visi na jamskem stropu. (Foto: A. Hudoklin)
9. Črnoglav morski zmaj (*Trachinus radiatus*) ima temno obarvano glavo, po kateri je tudi dobil ime. Ta barva lahko ob vznemirjenosti popolnoma izgine.
10. Oljčne vejice s plodovi. (Foto: D. Podgornik)

INDEX TO PICTURES ON THE COVER

FRONT COVER: Olive (*Olea europaea*) is a characteristic Mediterranean tree, with Slovenia representing the extreme edge of its range. (Photo: D. Podgornik)

1. One of the characteristics of the sage (*Salvia officinalis*) and wig tree (*Cotinus coggygria*) association is high species diversity and great breeding capacity of birds. (Photo: D. Podgornik)
2. Golden sea anemone *Condylactis aurantiaca* retracting into sand. (Photo: T. Turk)
3. Sea slug *Crataena peregrina* feeding on a hydrozoan. (Photo: T. Makovec)
4. Broad lobster *Scyllarus latus* is a less known species of long-tailed crabs. (Photo: E. Spanier)
5. According to some tradition, the olive branch is a symbol of peace, wisdom and triumph. (Photo: D. Podgornik)
6. Olive plantation in Slovene Istra. (Photo: D. Podgornik)
7. Mediterranean horseshoe bat (*Rhinolophus euryale*) with a well-seen horseshoe-shaped facial mask is one of the less known horseshoe bats in Slovenia. (Photo: A. Hudoklin)
8. Greater horseshoe bat (*Rhinolophus ferrum-equinum*) hanging from a cave ceiling. (Photo: A. Hudoklin).
9. Streaked weever (*Trachinus radiatus*) displays dark patterned head, which disappears completely if the fish is excited. (Photo: T. Turk)
10. Olive branches with fruits - olives. (Photo: D. Podgornik)



# ANNALES

**Anali za istrske in mediteranske študije  
Annali di Studi istriani e mediterraneei  
Annals for Istran and Mediterranean Studies  
series historia naturalis, 9, 1999**

**SUPPLEMENT**

**SREDOZEMSKO KMETIJSTVO IN OLJKARSTVO\***

**AGRICOLTURA E OLIVICOLTURA MEDITERRANEA**

**MEDITERRANEAN AGRICULTURE AND OLIVE GROWING**

**KOPER 1999**

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\* Prispevki s strokovnega posveta Sredozemsko kmetijstvo in oljkarstvo, ki sta ga organizirala Znanstveno-raziskovalno središče Republike Slovenije Koper in Društvo oljkarjev Slovenske Istre (DOSI) 12. novembra 1998 v Hotelu Belveder nad Izolo.

## VSEBINA / INDICE GENERALE / CONTENTS

|  |   |
|--|---|
| <b>Jorge E. Spangenberg &amp; Nives Ogrinc:</b><br>Characterization of olive oils from Slovenia<br>and Croatia by compound specific<br>isotope analysis ..... 1<br><i>Uporaba stabilnih izotopov ogljika pri<br/>karakterizaciji oljčnega olja iz Slovenije<br/>in Hrvaške</i> | <b>Bojan Butinar, Milena Bučar Miklavčič<br/>&amp; Darinka Čalija:</b> Skupni polifenoli, hidroksitirol<br>in tirosol v oljčnih oljih Slovenske Istre v dveh<br>zaporednih letih (1996, 1997) ..... 27<br><i>Total polyphenols, hydroxytyrosol and tyrosol<br/>in the olive oils of Slovene Istra in two<br/>consecutive years (1996, 1997)</i> |
| <b>Tom Levanič:</b> Težave pri ugotavljanju dejanske<br>starosti oljk ( <i>Olea europaea</i> L.) v Slovenski Istri ..... 5<br><i>Difficulties in the assessment of the actual<br/>age of olive trees (Olea europaea L.)<br/>in Slovene Istra</i>                               | <b>Bojan Butinar, Milena Bučar Miklavčič<br/>&amp; Darinka Čalija:</b> Tokoferoli v oljčnih oljih<br>Slovenske Istre v treh zaporednih letih ..... 37<br><i>Tocopherols in olive oils from Slovene Istra<br/>in three consecutive years</i>   |
| <b>Anamarija Plestenjak &amp; Terezija Golob:</b><br>Vrednotenje senzoričnih lastnosti oljčnih olj ..... 11<br><i>Evaluation of the sensory characteristics<br/>of olive oils</i>  | <b>Boštjan Godec, Boris Koruza, Barbara Ambrožič-<br/>Turk &amp; Viljanka Vesel:</b> Postopek pridobivanja<br>certificiranega sadilnega materiala<br>oljke ( <i>Olea europaea</i> L.) ..... 47<br><i>Procedure for the acquisition of certified oliva<br/>(Olea europaea L.) planting material</i>  |
| <b>Bojan Butinar, Milena Bučar Miklavčič<br/>&amp; Darinka Čalija:</b> Polifenoli v oljčnih oljih<br>Slovenske Istre letnika 94 ..... 17<br><i>Polyphenols in olive oils from<br/>Slovene Istra crop 94</i>  | <b>Viljanka Vesel:</b> Vpliv tretiranja in različnih<br>obdobij priprave potaknjencev na ukoreninjanje<br>dveh kultivarjev oljk ( <i>Olea europaea</i> ) ..... 53<br><i>Influence of treatment and different preparation<br/>period of cuttings on rooting of two olive<br/>varieties (Olea europaea)</i>                                       |

CHARACTERIZATION OF OLIVE OILS FROM SLOVENIA AND CROATIA  
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## ABSTRACT

The fatty acids of olive oils from Slovenia and Croatia were chemically and isotopically characterized. The analytical approach utilized combined gas chromatography - mass spectrometry (GC-MS) and the novel technique of compound specific isotope analysis (CSIA) through gas chromatography coupled to a stable isotope ratio mass spectrometer (IRMS) via a combustion (C) interface (GC-C-IRMS). This approach provides further insights into the control of the purity and the geographical origin of oils. The differences in the  $\delta^{13}\text{C}$  values of palmitic and oleic acids are discussed as the differences in biosynthesis of these acids in the plant tissue, admixing of distinct vegetable oils, and degradation of the lipids during oil extraction and refinement.

**Key words:** olive oil, vegetable lipids, carbon isotope, CSIA, adulteration, geographical origin

## INTRODUCTION

Stable carbon isotope analyses have proven to be a powerful tool for assessing the authenticity of vegetable food products from plants of different photosynthetic pathways (Doner, 1991). During photosynthetic fixation of carbon dioxide into plant biomass, plant cells discriminate against the heavier stable carbon isotope  $^{13}\text{C}$ . The most important atmospheric  $\text{CO}_2$ -fixing reactions are the  $\text{C}_3$  and  $\text{C}_4$  pathways (Farquhar *et al.*, 1989; O'Leary, 1988, 1993).  $\text{C}_3$  plants use the Calvin cycle for  $\text{CO}_2$  fixation, while the  $\text{C}_4$  plants use the Hatch-Stack cycle. All trees operate with the  $\text{C}_3$  pathway, and their carbon isotope compositions fall into the range of -34 to -22‰.  $\text{C}_4$  plants comprise most plants in the tropics, including tropical grasses, sedge, maize, sugar cane and salt marsh plants, and are isotopically heavier (-23 to -6‰). Factors other than the  $\text{CO}_2$ -fixation, however, may also have a less important impact on the isotopic

composition of plants and their products. These include plant growth rate, local atmospheric  $\text{CO}_2$  concentration, nutritional status of the cells, water availability, and cultivation practices (O'Leary, 1993). Therefore, the carbon isotopic composition of bulk oil and individual lipids may record the source and geographical origin of a plant product. Food chemists are increasingly using on-line gas chromatography - combustion - stable isotope ratio mass spectrometry (GC-C-IRMS) for carbon isotope analysis of the individual lipids as a tool for assessing adulteration of vegetable oils (Woodbury *et al.*, 1995; Kelly, 1997; Remaud, 1997). Previous work focusing on the chemical and isotopic composition of the major fatty acids (palmitic, stearic, oleic, and linoleic acids) of cold pressed (CP) olive oils from the main producing countries of the Mediterranean region were reported (Spangenberg *et al.*, 1998). We present herewith the isotopic compositions of fatty acids of the CP olive oils from Slovenia and Croatia.



## MATERIALS AND METHODS

Thirteen samples of extra virgin olive oil were obtained from Slovenia (Koper region, n=6) and Croatia (Istra, Dalmatia, n=7). All the samples were from the 1997-1998 olive season. The analytical approach combined chemical characterization of the fatty acid methyl esters (FAMES) by gas chromatography - mass spectrometry (GC-MS), and carbon isotope analyses of individual fatty acids by GC-C-IRMS. The bulk oils were analyzed for carbon isotope composition by combustion isotope ratio mass spectrometry using an on-line Carlo Erba 1108 elemental analyzer (EA) connected to a Finnigan MAT Delta S IRMS via a Conflo II split interface (EA-IRMS). All the analyses were performed at the Department of Earth Sciences of the University of Lausanne. The stable carbon isotope ratios are reported in the delta ( $\delta$ ) notation as the per mil (‰) deviations relative to the Pee Dee Belemnite limestone (PDB). The reproducibility of the EA-IRMS analyses was better than 0.1‰ (1 SD). Three to five replicate GC-C-IRMS runs were performed for each sample. The reproducibility ranged between  $\pm 0.1$  and  $\pm 0.4$ ‰ (1 SD). The accuracy of the GC-C-IRMS analyses was monitored by co-injection of a FAME laboratory standard of the known isotopic composition. The isotopic shift due to the carbon introduced in the fatty acid methylation was corrected by a mass balance equation (Spangenberg *et al.*, 1998).

## RESULTS AND DISCUSSION

## Fatty acids composition

The scatter of the compositions of fatty acids for the virgin olive oils probably reflects the variation in variety, climatic conditions of the area, water-use efficiency in cultivars, salinity, temperature and pH of the irrigation water, olive-ripening stage and other factors (results not shown for brevity).

## Bulk isotopic composition

The  $\delta^{13}\text{C}$  of the bulk olive oils (-27.7 to -30.6‰) show isotopic compositions typical of  $\text{C}_3$  plants (Tab. 1). The scatter of the  $\delta^{13}\text{C}$  values of the oils (2.9‰) may be attributed to factors affecting the chemical distribution of the fatty acids, and particularly by the physiological processes and enzymatic reactions occurring in the plant cells. Additionally, the chemical changes (transmerization of oleic acid and oxidation) during thermal degradation (natural or induced during steam washing or other refining procedures) of the olive oil, or blending of CP oil with refined olive oil or other vegetable oil may cause a further isotopic discrimination.

Tab. 1: Carbon isotope composition of bulk oil and main individual fatty acids in olive oil samples from Slovenia and Croatia.

Tab. 1: Izotopska sestava celokupnega ogljika in ogljika posameznih maščobnih kislin v vzorcih oljčnih olj iz Slovenije in Hrvaške.

| Sample  | Country  | $\delta^{13}\text{C}$ (‰ PDB) |                 |                |              |
|---------|----------|-------------------------------|-----------------|----------------|--------------|
|         |          | bulk oil                      | palmitic (16:0) | stearic (18:0) | oleic (18:1) |
| COIL-58 | Slovenia | -30.1                         | -34.3           | -33.3          | -34.1        |
| COIL-59 | Slovenia | -28.4                         | -31.4           | -31.3          | -30.1        |
| COIL-60 | Slovenia | -29.4                         | -32.1           | -32.2          | -30.1        |
| COIL-75 | Slovenia | -29.1                         | -32.8           | -32.2          | -31.6        |
| COIL-76 | Slovenia | -30.0                         | -33.5           | -              | -33.6        |
| COIL-79 | Slovenia | -29.1                         | -32.4           | -32.8          | -31.9        |
| COIL-65 | Croatia  | -29.6                         | -32.9           | -32.4          | -31.0        |
| COIL-66 | Croatia  | -29.4                         | -31.8           | -32.0          | -30.3        |
| COIL-67 | Croatia  | -29.1                         | -30.6           | -31.5          | -30.7        |
| COIL-68 | Croatia  | -29.8                         | -33.3           | -32.7          | -31.3        |
| COIL-77 | Croatia  | -30.6                         | -35.0           | -              | -33.1        |
| COIL-78 | Croatia  | -27.7                         | -31.8           | -              | -32.6        |
| COIL-80 | Croatia  | -28.0                         | -35.4           | -31.2          | -32.3        |

- = not analysed

### Isotopic composition of individual fatty acids

The  $\delta^{13}\text{C}$  values of the virgin olive oil fatty acids vary between -34.1 to -28.5‰ (Table 1). A substantial separation of the oils from the 1:1 line in the  $\delta^{13}\text{C}_{16:0}$  vs.  $\delta^{13}\text{C}_{18:1}$  diagram (16:0 = palmitic acid, 18:1 = oleic acid) suggests admixing of cold pressed virgin olive oil with refined olive oils or other vegetable oils of different 18:1/16:0 concentration-ratios than the genuine olive oil. The distribution of the samples in the  $\delta^{13}\text{C}_{16:0}$  vs.  $\delta^{13}\text{C}_{18:1}$  diagram strongly suggests the adulteration or inappropriate processing of some CP olive oils (Fig. 1). Virgin CP olive oils are separated from the lower grade olive oils by dedicated principal component analysis performed combining the fatty acid composition and the bulk and molecular carbon isotope ratios (results not shown for brevity).

### CONCLUSIONS

The  $\delta^{13}\text{C}$  values of the bulk oil and individual fatty acids can be used for identification of the sources of olive oil and control of their authenticity. The use of  $\delta^{13}\text{C}_{16:0}$  vs.  $\delta^{13}\text{C}_{18:1}$  covariations serves to assess cases where impurity or adulteration is suspected. Blending of olive oil with edible oils with slightly different fatty acid compositions (e.g., olive pomace, sunflower, hazelnut) may be detected using this approach combined with molecular information (GC-MS) and the carbon isotope composition of the bulk oil.

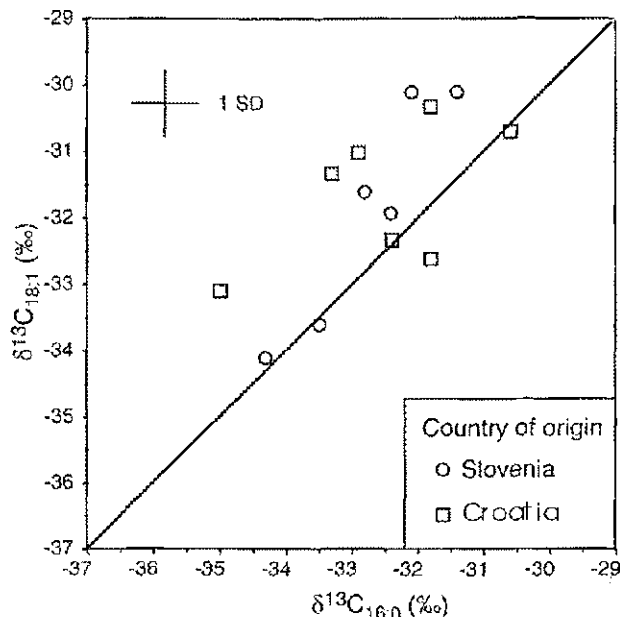


Fig. 1: Carbon isotope composition of oleic acid ( $\delta^{13}\text{C}_{18:1}$ ) vs. palmitic acid ( $\delta^{13}\text{C}_{16:0}$ ) of olive oils from Slovenia and Croatia.

Sl. 1: Izotopska sestava ogljika oleinske kisline ( $\delta^{13}\text{C}_{18:1}$ ) v odvisnosti od izotopske sestave ogljika palmitinske kisline ( $\delta^{13}\text{C}_{16:0}$ ) v vzorcih oljčnih olj iz Slovenije in Hrvaške.

### ACKNOWLEDGEMENTS

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## UPORABA STABILNIH IZOTOPOV OGLJIKA PRI KARAKTERIZACIJI OLJČNEGA OLJA IZ SLOVENIJE IN HRVAŠKE

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### POVZETEK

Meritve izotopske sestave ogljika so se izkazale kot izvrstno naravno sledilo za spremljanje različnih procesov, zato jih s pridom izkoriščamo tudi v živilski industriji pri določanju kakovosti in pristnosti (avtentičnosti) različnih živil - vin, sadnih sokov, medu, olj. Poleg tega se stabilni izotopi uporabljajo tudi pri določitvi geografskega porekla.

V prispevku, ki je nastal v sodelovanju z Laboratorijem za stabilne izotope, Inštituta za mineralogijo in petrologijo Univerze v Luzani v Švici, smo predstavili uporabo stabilnih izotopov ogljika pri določitvi avtentičnosti in geografskega porekla oljčnega olja. Določili smo kemijsko in izotopsko sestavo maščobnih kislin v oljčnih oljih iz Slovenije in Hrvaške. Koncentracije maščobnih kislin smo določili s plinskim kromatografom s kapilarno kolono (GC-MS), njihovo izotopsko sestavo ( $\delta^{13}\text{C}$ ) pa z masnim spektrometrom za stabilne izotope GC-C-IRMS. Iz korelacije med izotopsko sestavo ogljika palmitinske kisline,  $\delta^{13}\text{C}_{16:0}$ , od izotopske sestave ogljika oleinske kisline,  $\delta^{13}\text{C}_{18:1}$ , lahko ugotovimo možne potvorbe in nepravilno predelavo oljčnega olja. Drugi možni vzroki, ki privedejo do razlik med vrednostmi  $\delta^{13}\text{C}_{16:0}$  in  $\delta^{13}\text{C}_{18:1}$ , so še: različna biosinteza teh kislin v rastlinskih tkivih ter razgraditev maščob pri ekstrakciji olj in nadaljnjem čiščenju ekstrakta.

**Ključne besede:** oljčno olje, rastlinske maščobe, izotopi ogljika, C<sub>18</sub>A, potvorjenost, geografsko poreklo

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## TEŽAVE PRI UGOTAVLJANJU DEJANSKE STAROSTI OLJK (*OLEA EUROPAEA* L.) V SLOVENSKI ISTRI

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### IZVLEČEK

V prispevku obravnavamo probleme pri ugotavljanju starosti oljk (*Olea europaea* L.) v slovenski Istri. Oljka zaradi načina rasti ne tvori tipičnih prirastnih plasti, kot jih poznamo pri drugih drevesnih vrstah zmernih klimatskih con. Zanimiv je pojav inicialnega ranega lesa, ki kaže na zgodnji začetek kambijeve rasti. Netipična zgradba branike in občutljivost na pozebe otežita natančno ugotavljanje starosti. Zaradi tega v večini primerov ugotavljamo le starost trenutno živih nadzemnih delov oljke, nikakor pa ne starosti oljke kot celote.

**Ključne besede:** Oljka, *Olea europaea*, oljkarstvo, zaščita naravne in kulturne dediščine, dendrokronologija, lesna anatomija, Slovenija, slovenska Istra

### UVOD

Oljka spada v red Oleales in edino družino tega reda Oleaceae. Poleg oljke (*Olea europaea*), krajši opis je na sliki 1, spadajo v to družino še španski bezeg (*Syringa vulgaris*), vsi jeseni (*Fraxinus* spp.) in nekaj grmovnic iz rodov *Jasminum*, *Forsythia* in *Ligustrum*. V Sloveniji se srečamo z vsemi predstavniki te družine. Nekateri med njimi so pomembne gospodarske rastline, npr. jeseni in oljka, drugi imajo pomembno vlogo v vrtinarstvu - jasmini, španski bezeg, forzicije in kalina. Z izjemo oljke so vse vrste dobro prilagojene klimatskim razmeram pri nas. Oljka je v slovenski Istri na skrajnem severnem robu ekološkega areala in je zaradi tega zelo občutljiva na nizke zimske temperature. Ugotovitve kažejo, da so temperature pod  $-4^{\circ}\text{C}$  že kritične (Vesel, 1998). Negativni vpliv nizkih zimskih temperatur se kaže v različnih stopnjah poškodovanosti kambija in temu posledičnem delnem ali popolnem odmrtju nadzemnega dela drevesa.

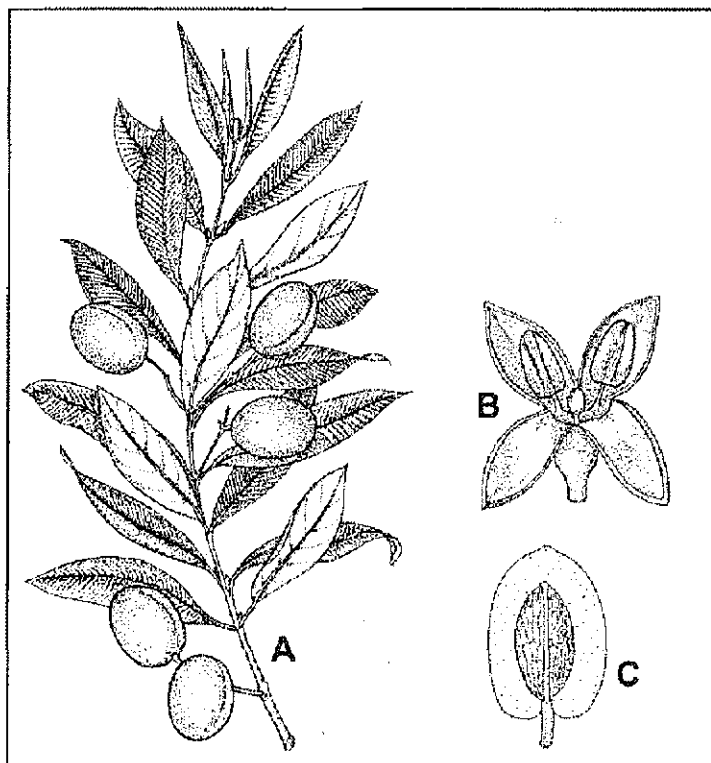
Gospodarski pomen oljk, predvsem pa oljčnega olja je v Istri zelo velik. Tako najdemo prve zapise o oljčnem

olju slovenske Istre že v besedilih grškega filozofa Pavzanija iz 2. stoletja pred našim štetjem (Butinar, 1998). Prvi dekreti, ki so urejali področje proizvodnje in trgovine z oljčnim oljem, pa segajo v leto 1383. Kasneje so imeli Benečani strog nadzor nad prometom istrskega oljčnega olja čez morje v Beneško republiko (Darovec, 1998). Danes je oljkarstvo pomembna gospodarska dejavnost in je pomemben vir dohodka za lokalno prebivalstvo.

### Cilj

Namen prispevka je z lesno anatomskega vidika preučiti zgradbo branike oljke ter na osnovi teh spoznanj pristopiti k pravilni makroskopski identifikaciji branik in s tem posredno k pravilnem ugotavljanju starosti oljk.

Prispevek je nastal v okviru petletnega, aplikativnega projekta Ministrstva za znanost in tehnologijo "Oljka v slovenski Istri - naša kulturna dediščina". Kofinanserja projekta sta še Ministrstvo za kmetijstvo, gozdarstvo in prehrano ter Društvo oljkarjev slovenske Istre.



**Sl. 1:** *Oljka (Olea europaea) prikazana shematsko. A: oljčna vejica s plodovi - oljkami, B: zvezdast cvet oljke je sestavljen iz 4 zraslih časnih in 4 zraslih venčnih listov, dva prašnika sta prirasla na cvetna lista, plodnica je dvo karpelna in nadrasla, C: prerez ploda z jasno vidno koščico (slika povzeta po Mägdefrau & Ehrendorfer, 1978).*

**Fig. 1:** *Schematic presentation of the olive (Olea europaea). A: olive branch with fruits - olives, B: regular flower with 4 fused sepals and 4 fused petals, two stamens fused with petals and bicarpelous superior ovary, C: transection of the fruit with clearly visible stone (hand endocarp) (according to Mägdefrau & Ehrendorfer, 1978).*

#### MATERIAL IN METODA

Analizirali smo koluta dveh starih oljk - enega z Raba (Hrvaška), drugega iz Padne (Slovenija). Površino kolotov smo najprej poravnali z obličem, nato pa pobrusili z brusnimi papirji različne gradacije. Končno brušenje smo opravili z ultrafinimi brusnimi papirji, ki površine ne brusijo, ampak gladijo. Tako smo zagotovili najboljšo možno vidljivost branik.

Starost oljk smo ugotavljali na zglajenih kolutih s štejem branik. Branika je definirana kot letni prirastek drevesa, letnica pa kot meja med dvema branikama (Torelli, 1990). Branike smo šteli s stereo mikroskopom pri povečavi 20-110x. Širine branik smo merili na merilni mizici LINTAB, meritve pa smo zajemali in obdelovali z računalniškim programom TSAP/x.

Poleg makroskopske analize smo opravili tudi mikroskopsko analizo lesa oljke. Za mikroskopsko analizo smo orientirane vzorce lesa velikosti cca. 1x1x1 cm najprej več dni prepažali z mešanico vode in glicerina.

Za mikroskopsko analizo smo pripravili trajne, obarvane, prečno, radialno in tangencialno orientirane, 15 µm debele preparate.

#### REZULTATI IN DISKUSIJA

Makroskopsko je les oljke zaradi velike gostote (do 1000 kg/m<sup>3</sup>) dokaj homogen, vendar z lokalno močno razgibano rastjo, zlasti dekorativen je kontrast med črnjavo in beljavo. Les je zelo primeren za struženje, izdelavo intarzij in za zelo vreden parket. Uporablja se za izdelavo skulptur, zlasti v mediteranskem prostoru, in za umetniške izdelke, predvsem posodje (Begeman, 1963).

Branike so pri oljki zelo slabo vidne. Slabo so vidne zato, ker je razlika v anatomski zgradbi ranega in kasnega lesa zelo majhna. Tudi letnica je zaradi dokaj specifičnega ravnega ritma neizrazita. Na osnovi makroskopskega videza branike sklepamo, da kambij\* verjetno začne rasti že zelo zgodaj. V ugodnih klimatskih

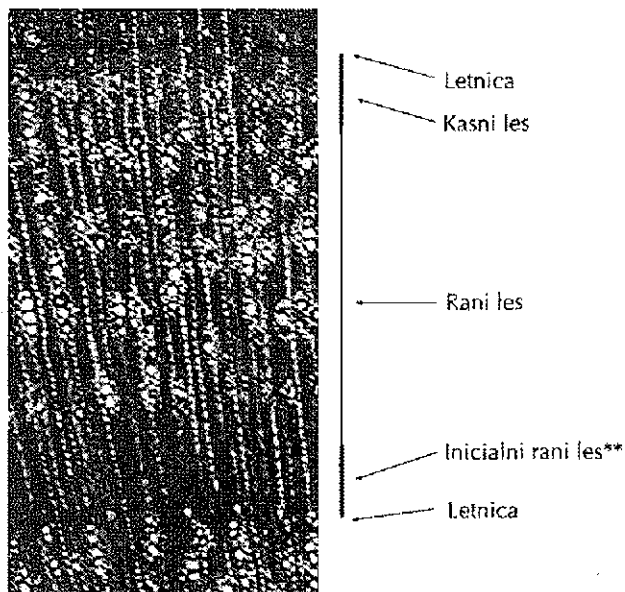
\* Kambij je sloj aktivno delečih se celic, ki navzven proizvajajo sekundarni floem, navznoter pa sekundarni ksilem (Torelli, 1990).

razmerah je to lahko že v drugi polovici februarja ali v začetku marca. Zelo verjetno je to posledica dejstva, da je oljka zimzelena in listnega aparata pozimi ne odvrže, zato lahko začne rasti, takoj ko so rastne razmere dovolj ugodne za to; viri navajajo, da se rast lahko začne, ko temperatura preseže 10°C (Larcher, 1980).

Mikroskopska analiza strukture branike pri oljki pokaže zelo zanimivo sliko (sl. 2). Na začetku nastane ožji pas inicialnega ranega lesa\*\*, sledi mu rani les s širokimi trahejami in nato kasni les. Pojav inicialnega ranega lesa čisto na začetku branike in s tem na začetku vegetacijske sezone je še posebej zanimiv, saj v literaturi (Schweingruber, 1990) podatkov o njem ni opaziti, zato se mu bomo v prihodnje bolj posvetili.

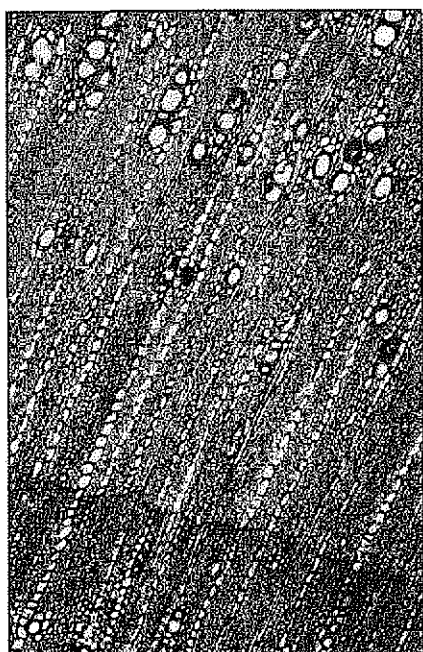
Les oljke smo analizirali tudi v vseh treh anatomskih prerezih - prečnem, radialnem in tangencialnem.

Zaradi zgoraj opisanih anatomskih posebnosti zgradbe branike oljke je identifikacija branik in letnic in s tem neposredno določanje starosti dreves zelo zahtevna naloga. Že tako zahtevno nalogo dodatno otežuje še dejstvo, da je oljka v slovenski Istri na robu svojega ekološkega areala in jo zato velikokrat prizadenejo mrzle in vetrovne zime. V posebno mrzlih zimah lahko odmre celoten nadzemni del. Koreninski sistem ponavadi preživi pozebo in naslednjo pomlad oljka praviloma bogato odžene iz panja.



Sl. 2: Zgradba prečnega prereza branike oljke (*Olea europaea* L.), shema T. Levanič.

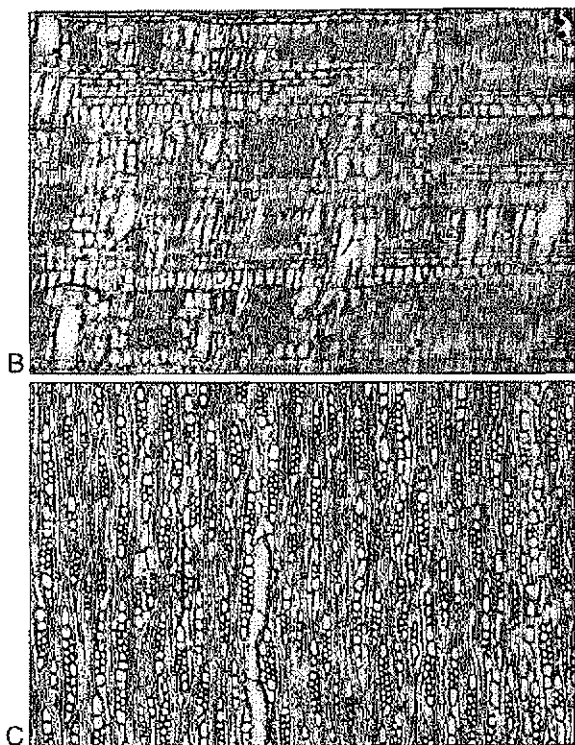
Fig. 2: Structure of the transverse section of the olive's (*Olea europaea* L.) annual ring; scheme by T. Levanič.



Prečni prerez (pov. 20x)

Oljka je difuzno porozna vrsta. Traheje so v kratkih radialnih nizih, največkrat po 2 do 4 v skupini, redkokdaj posamezne. Trahejni členi imajo debele celične stene. Letnice so pogosto nejasne. Aksialni parenhim je paratrahealen, velikokrat se pojavlja tudi marginalni aksialni parenhim v pasovih, širokih 1-3 celice. Razmerje med deležem vlaken in parenhima je zelo spremenljivo.

\*\* Inicialni rani les je posebna oblika ranega lesa, ki je po morfoloških in fizioloških lastnostih povsem podoben kasnemu lesu. Za razliko od kasnega lesa, ki nastaja v drugi polovici vegetacijske sezone (julij, avgust in september) pa inicialni rani les najverjetneje nastaja v februarju ali marcu.



Radialni prerez (pov. 20x)

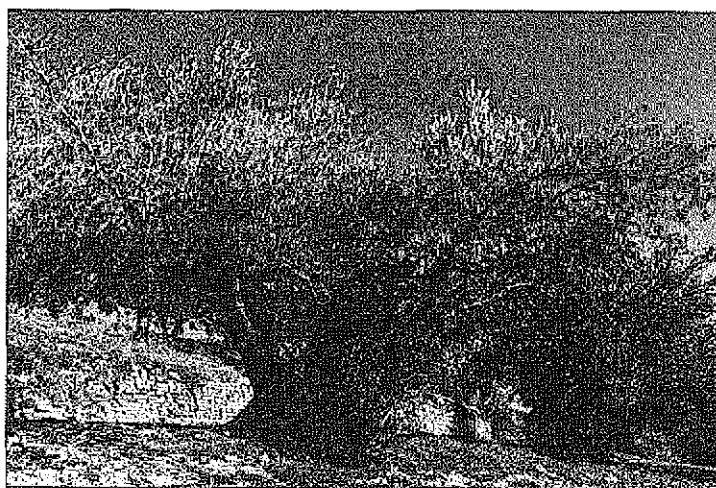
Perforacije trahejnih členov so preproste. Trakovi so heterogeni, sestavljeni iz ležečih in kvadratnih celic. Piknje med trakovi in trahejami so številne, drobne in okrogle. V trahejah črnjave so depoziti gumoznih snovi. Vlaknasto osnovno tkivo sestavljajo izključno libriformska vlakna. Trahejni členi imajo helikalne odebelitve. Potek aksialnih elementov je pogosto nepravilen. V teh območjih so trakovi kratki in široki. V celicah trakov so pogosto zelo majhni iglasti kristali.

Tangencialni prerez (pov. 20x)

Trakovi so dvo do tri redni, zelo redko enoredni, do 12 celic visoki. Celice so v osrednjem delu trakov majhne in ovalne, robne celice velike in precej vzolžno podaljšane.

Sl. 3: Les oljke v treh anatomskih prerezih: A-prečni, B-radialni in C-tangencialni. Povečava 20-kratna (fotografije T. Levanič).

Fig. 3: Olive's wood in three anatomic sections: A-cross, B-radial, and C-tangential. Magnification x 20 (photos by T. Levanič).



Sl. 4: Tipična forma oljk v slovenski Istri (na sliki oljke iz Padne). Zaradi pogostih pozeh nadzemni del odmre, oljke pa kmalu bogato odženejo iz panja (puščice). Večinoma kmetje pustijo le nekaj debel in jih negujejo dalje (foto Z. Primožič in T. Levanič).

Fig. 4: Typical form of the Slovene Istra olives (photograph showing olives from Padna). Due to frequent frost, the above-ground part dies away, but the olives soon spring up opulently from the coppice (arrows). Farmers mostly choose to leave only a few stems and then nurse them (photos by Z. Primožič and T. Levanič).



Tako je bilo leta 1929 zaradi izredno nizkih zimskih temperatur, podkrepjenih z burjo, prizadetih precej oljk v slovenski Istri, vendar so se kasneje bolj ali manj uspešno obnovile iz panja. Zaradi tega ugotovljene starosti oljk v slovenski Istri niso tako visoke, kot je bilo sprva pričakovati. Za oljko iz Padne smo ugotovili, da je stara le okoli 76 let, za oljko z Raba pa, da ima med 110 in 120 let.

Na osnovi ustnih virov sklepamo, da so bile preučevane oljke iz Padne posajene mnogo prej, kot kažejo naši podatki o starosti. Zaradi tega moramo pojem starosti pri oljki razumeti čisto drugače, veliko bolj kompleksno kot pri drugih drevesnih vrstah. Oljka se odlikuje po svoji trdoživosti; če oljki odmrje nadzemni del, se le-ta dokaj hitro obnovi iz preživelega podzemnega dela. Ta način obnove drevesa bi zato lahko primerjali s panjevskim gospodarjenjem v gozdarstvu. Tudi tam prave starosti dreves ne moremo določiti, lah-

ko ugotovimo le starost trenutno rastočega nadzemnega dela, medtem ko je panj ponavadi veliko starejši. Problem, na katerega naletimo pri določanju starosti panjev, je, da panji v 30 do 40 letih strohnijo in izginejo, tako da so praktično neuporabni za ugotavljanje starosti.

Alternativa določanju starosti nadzemnega dela je ugotavljanje starosti korenin, vendar tudi tu naletimo na kup težav. Osnovna značilnost koreninskega sistema je namreč dokaj hitro obnavljanje, stare korenine odmirajo, namesto njih nastajajo nove, ki opravljajo funkcijo, dokler se ne izčrpajo, nato pa njihovo vlogo prevzamejo nove korenine.

Na osnovi vsega povedanega lahko torej zaključimo, da ugotavljanje starosti oljk ni ozko vezano na natančne dendrokronološke analize, temveč tudi na ustne vire, podatke o rabi zemljišč iz katastrov in na različne pisane in slikovne vire.

## DIFFICULTIES IN THE ASSESSMENT OF THE ACTUAL AGE OF OLIVE TREES (*OLEA EUROPAEA L.*) IN SLOVENE ISTRA

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### SUMMARY

*The article tackles the problems encountered when trying to assess the age of olives (*Olea europaea L.*). Due to its manner of growth, the olive does not form typical further layers as known in other tree species of the moderate climate zones, but can say that its annual growth of layers is similar more to the growth rhythms of subtropical trees. From the structure of the annual ring we can infer that olives begin to grow very early, probably towards the end of February with the occurrence of a narrow belt of the initial early wood followed by early and late wood. It stops growing relatively late, probably at the end of October, with the unfavourable growing conditions. The problem of whether the cambium's winter dormancy is complete or not will have to be dealt with in greater detail.*

*The atypical structure of the annual rings greatly aggravates an accurate determination of new layers and with it connected accurate assessment of age. This is further hindered by the great sensitivity of olives to winter temperatures. Due to the frequent irruption of cold air into Slovene Istria, the olives are often nipped by frost. Subject to the intensity of frost, the entire above-ground parts of the affected trees can die away either partially or totally. But as the olives are successful survivors, they renew quickly with opulent growth from the coppice. Owing to such manner of renewal, the assessment of an olive's age is practically impossible, for only the age of momentarily alive above-ground parts are assessed, and in no way the age of an olive as a whole.*

*The cognitions of the preliminary research in the growth of olive trees have shown that their age will have to be understood in much broader sense not merely within the framework of the actual age of the momentarily living part above the ground. In the assessment of an accurate, although only general age of olive trees we will clearly have to rely on the cadastre records and other written as well as pictorial sources.*

**Key words:** olive tree, *Olea europaea*, olive growing, protection of natural and cultural heritage, dendrochronology, wood anatomy, Slovene Istria

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## VREDNOTENJE SENZORIČNIH LASTNOSTI OLJČNIH OLJ

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### IZVLEČEK

*Kemijska analiza oljčnega olja ne zadostuje za celovito oceno njegove kakovosti. Oceniti je treba tudi senzorične lastnosti in ravno te so po mnenju strokovnjakov odločilni kriterij kakovosti oljčnega olja. V prispevku so podane fiziološke osnove, metode in pogoji za senzorično ocenjevanje. Predstavljen je sistem za senzorično ocenjevanje deviškega oljčnega olja, kot ga predlaga Mednarodni svet za oljčno olje, t.j. potrebna oprema in prostor, metodologija in kriteriji za izbor pokuševalcev, slovar izrazov, ki opisujejo negativne in pozitivne lastnosti olj, ter obdelava in predstavitev rezultatov preskušanja.*

**Ključne besede:** oljčno olje, senzorična analiza, metoda

### UVOD

S kemijsko analizo nekega živila lahko določimo in identificiramo na desetine ali stotine spojin, ki dajejo živilu njegove senzorične lastnosti. In ker se znanje povečuje in se analizne metode iz dneva v dan izpopolnjujejo, je seznam za nalizo določenih in identificiranih sestavin vse daljši. Če bi strokovnjak, ki se ukvarja z aromami, želel aromo živila oceniti samo na podlagi instrumentalne analize, bi moral v tej množici spojin prepoznati tiste, ki so pomembne oz. odločilne za aromo živila. Za to potrebuje poleg analizičnih metod tudi senzorično vrednotenje. Potrebuje torej človeka.

Človek zaznava svet okoli sebe ob pomoči svojih čutov ali, natančneje, ob pomoči senzoričnih receptorjev, ki so detektorji fizikalnih in kemijskih sprememb v okolju in organizmu. Senzorični receptorji so specializirane receptorske celice ali posebna mesta na njih, ki se navadno odzivajo le na eno vrsto dražljaja (gustatorni dražljaj ne stimulira vizualnega receptorja). Receptorji reagirajo na zunanji dražljaj z električnim

impulzom, ki se po živčnih vlaknih prenese v ustrezno možgansko središče. Tu se registrira, prepozna in ovrednoti. Sledi premislek in reakcija nanj (Fricker, 1984).

### SENZORIČNA ANALIZA

Senzorična analiza, t.j. vrednotenje lastnosti živila s čutili, je najstarejši način preverjanja kakovosti hrane. Z izbiranjem ali konzumiranjem hrane jo hote ali nehote, vede ali nevede ocenjujemo in jo na podlagi svoje ocene izberemo ali zavrnemo.

Senzorično ocenjevanje živila je torej analizični postopek, pri katerem opišemo in ocenimo njegove lastnosti ob pomoči svojih čutov. Pri tej analizi ima vlogo analiznega instrumenta človek. Pri senzoričnem ocenjevanju uporablja svojih pet čutov: za okus, voh, vid, tip in sluh (Jellinek, 1981). Čut je sposobnost za sprejemanje fizičnih in kemijskih dražljajev iz okolice.

Okus je čut za zaznavanje značilnosti jedi ob pomoči okušalnega organa v ustih. Okus je tudi značilnost jedi, ki še zaznava s čutom za okus. To so vsi senzorični

vtisi, zaznaniv ustih: na jeziku, nebu, v žrelu, torej v celotni ustni votlini. Zaznavo okusa omogoča gustatorni (okušalni) organ, to so okušalni mešički, ki so razporejeni po površini okušalnih brbončic, te pa so posejane po vsej površini jezika, na mehkem nebu in v žrelu. Okušalni mešički so sodčkaste tvorbe, v vsaki je 20 do 30 receptorskih celic.

Da bi lahko zaznali okus določene snovi, morajo molekule te snovi priti v stik z gustatornimi celicami. Predpogoj za to je, da je ta snov topna v vodi, t. j. v slini, ki pokriva površino jezika in obliva oz. napolnjuje okušalni mešiček. Danes velja, da poznamo štiri osnovne okuse, sladko, grenko, kislo in slano. Med osnovne okuse prištevamo v zadnjem času tudi *umami* (japonska beseda, ki pomeni okusno, slastno), to je okus natrijevega glutamata, inozin-monofosfata, guanozin-monofosfata.

Mehanizem medsebojnega delovanja snovi, ki je nosilec okusa in gustatornih receptorjev, še ni popolnoma pojasnjen. Čas, ki poteče od kontakta snovi z receptorsko celico do zaznave okusa, je za različne okuse različno dolg. To moramo upoštevati, če želimo med pokušanjem zaznati vse okuse. Življenjska doba gustatornih celic je od 12 do 20 dni. Sposobnost okušanja je prirojena, med populacijo lahko variira za faktor 100. Pragi prepoznave posameznih okusov pomenijo tiste koncentracije, ki jih polovica populacije pravilno prepozna.

Vonj je značilnost snovi, ki se zaznava z vohom. Vonj ima za človeka dva pomena: je parameter dobre, ustrezne kakovosti, je pa tudi indikator kvara, škodljivosti. Občutljivost za vonj je pri človeku veliko večja kot občutljivost za okus. Ocenjujejo (Fricker, 1984), da je približno 5.000 spojin, ki imajo za človeka vonj in jih lahko zavohamo. Sposobnost vohanja je dedna, s staranjem se spreminja, nanjo vpliva tudi spol.

Periferni receptorji vohalnih dražljajev so posebne vohalne celice, nameščene na površini 1,5 cm, na stropu nosne votline. Življenjska doba olfaktornih receptorjev je od 3 mesecev do 1 leta. Snov zavohamo tako, da pride zrak s hlapnimi snovmi do olfaktornih receptorjev skozi nos ali skozi žrelo s tokom vdihnjene ali izdihnjene zraka. Tretja možnost je, da hlapne snovi difundirajo iz kapilar v nosni votlini.

Hlapne snovi, ki pridejo v nosno votlino, stimulirajo poleg vohalnih receptorjev tudi končiče trigeminalnega živca, ki oživčuje ustno in nosno votlino, sodeluje pri motoriki govora, zvečenju in je odgovoren za zaznavo bolečine, toplote. Sodeluje pri vohanju in pri okušanju. Omogoča zaznavo senzoričnih lastnosti, ki so večini ljudi neprijetne, ostre, dražeče vonje in okuse in s tem skrbi, da te snovi ne vzdrazijo premočno receptorjev, kar bi povzročilo bolečino (gorčica, hren, ogljikov dioksid v pijačah, mentol, čebula, poper).

Voh je za človeka zelo pomemben čut, ker skupaj z okusom in s tipnimi zaznavami oblikuje aromo.

Človek je sposoben razlikovati številne vonje, težave pa povzročajo ubeseditev zaznave. Kombinacijo več vonjev zaznamo kot celoto in ne kot zmes posameznih vonjev. Zato je profiliranje vonjev in opisovanje arome težavna naloga, ker ne moremo predvideti, ali bo v medsebojnem učinkovanju različnih vonjev prišlo do pojačanja ali maskiranja.

Poznamo rek: Z očmi jemo. Vid nam omogoča, da hrano zaznamo na daljavo in se nanjo odzovemo, ko je še ne vohamo ali okušamo. Človekovo oko reagira le na vidni del elektromagnetnega spektra med  $\lambda=400$  in  $\lambda=700$  nm. Vizualna zaznava je rezultat reakcij, do katerih pride, ko elektromagnetno valovanje pade v oko in vzdrazijo vidne receptorje. V očesu sta dva tipa receptorjev, čepki in palčke. Čepki posredujejo zaznavo barve in so občutljivi pri zmerni in visoki energiji (dnevna svetloba), palčke pa omogočajo gledanje v mraku.

Tip je kombinacija dveh vrst zaznav: kinestetičnih, ki se nanašajo na občutek gibanja in somestetičnih, ki se nanašajo na pritisk, dotik. Kombinacija obeh vrst zaznav posreduje zaznavo, ki ji rečemo občutek v ustih in tekstura.

Za neoporečno izvedbo senzoričnega ocenjevanja, ki da ponovljive rezultate, je treba zagotoviti pogoje, ki so definirani, kontrolirani in ponovljivi. Tu je mišljen prostor, vzorci, pribor, metode, ocenjevalci in obdelava rezultatov.

Ocenjevalci morajo biti zdravi, odgovorni, zanesljivi in povprečno občutljivi ljudje, z dobrim senzoričnim spominom, motivirani za delo v senzorični komisiji. Prostor za senzorično analizo mora biti namenjen in uporabljan le za senzorično ocenjevanje, biti mora ločen od pomožnih prostorov, dovolj velik, zračen, primerno osvetljen, z udobnimi in ustrezno opremljenimi ocenjevalnimi kabinami (ISO 8589). Vzorci morajo biti reprezentativni, šifrirani in vsi enako predstavljeni. Pribor in vsi drugi pogoji za ocenjevanje morajo biti izbrani tako, da ne vplivajo na senzorične lastnosti ocenjevanih vzorcev (ISO 6658).

Za senzorično ocenjevanje uporabljamo dve skupini metod (Fricker, 1984):

- analitske, pri katerih preizkušanje poteka po natančnem, vnaprej določenem načrtu,
- afektivne (hedonske), pri katerih je naloga ocenjevalcev, da v oceni podajo svoj osebni odnos do ocenjevanega vzorca.

### SENZORIČNO OCENJEVANJE OLJČNEGA OLJA

Kakovost oljčnega olja je odvisna od številnih faktorjev: od kultivarja, od tal, na katerih rastejo oljke, od klime, nadmorske višine, časa in postopkov pri obiranju, stopnje zrelosti in zdravja plodov, časa in razmer za skladiščenje oljk pred stiskanjem olja, tehnološkega postopka pridobivanja olja ter časa in razmer za skladiščenje olja (Kiritsakis, 1998).

S kakovostjo je mišljena kemijska sestava in z njo povezane senzorične lastnosti olja. Za aromo olja so odgovorne hlapne sestavine, to so aldehidi, ketoni, estri, nasičeni in nenasičeni alkoholi in druge spojine. Okus pa poleg naštetih sestavin oblikujejo še maščobne kisline (predvsem oleinska, linolna in linolenska) in polifenoli. Vsaka hlapna komponenta ima značilen vonj (zbadajoč, kovinski, saden, po jabolku, svež, sladek itd.), tako da je aroma olja odvisna od prevladujoče hlapne komponente.

Prav senzorične lastnosti so po mnenju strokovnjakov odločilni kriterij kakovosti oljčnega olja. Zato ni vseeno, kako senzorično ocenjevanje poteka in kdo ga opravlja. Da bi dobili metodo, ki bi dala kar najbolj zanesljive rezultate, so bile opravljene številne študije o tehnikah senzoričnega ocenjevanja deviškega oljčnega olja (Kiritsakis, 1998).

Rezultat je *"Metoda za organoleptično ocenjevanje deviškega oljčnega olja"*, ki jo je l. 1987 predlagal in l. 1991 dopolnil Mednarodni svet za oljčno olje (IOOC). S to metodo so določena merila za senzorično ocenjevanje arome deviškega oljčnega olja. Oblikovan je primeren slovar izrazov za opis lastnosti olja, standardizirani so pogoji za ocenjevanje, predpisana je izbira pokuševalcev in oblikovan je sistem razvrščanja olj, ki sloni na opisni analizi pozitivnih in negativnih lastnosti deviških oljčnih olj.

Aroma oljčnega olja je definirana kot kombinacija olfaktornih, gustatornih in trigeminalnih občutkov, zaznanih med okušanjem.

Senzorične lastnosti oljčnega olja opisujejo s številnimi izrazi, ki se nanašajo na okus, vonj in trigeminalne zaznave. Navadno ti izrazi niso imena določenih kemijskih substanc, ampak so asociacije na živila, predmete ali lastnosti, katerih okus, vonj ali aroma je mogoče zaznati v oljčnem olju.

Kakovost deviškega oljčnega olja se ocenjuje po metodi, predpisani z Normativom 2568/91 EU. Značilnost te metode je, da sloni na preprosti opisni analizi, torej so za opis pozitivnih in negativnih lastnosti ocenjevanega deviškega oljčnega olja predlagani ustrezní izrazi. Ocenjevalci pri opisovanju ocenjevanega olja ne smejo uporabljati svojih lastnih izrazov, ampak izključno izraze iz specifičnega senzoričnega slovarja za oljčno olje. Slovar navaja in definira 31 izrazov. Zelo pomembno je, da se ljudje, ki senzorično ocenjujejo oljčno olje, s tem slovarjem strinjajo, da vse navedene izraze sprejmejo in da imajo zanje vsi izrazi enak pomen.

To pa ni edina zahteva za osebe, ki delajo kot pokuševalci oljčnega olja. Ustrezati morajo splošnim zahtevam, kot je npr. fizično in psihično zdravje, izpolnjevati zahteve v zvezi s kajenjem, uživanjem hrane, uporabo dišečih higienskih in kozmetičnih

sredstev. Poleg tega morajo biti za delo zainteresirani in motivirani ter primerno občutljivi (ISO 6658).

Občutljivost kandidatov preverijo z zelo zahtevnim preskušanjem. Najprej za vsako od štirih nezaželenih lastnosti (pregreto-plesnivo, zakisano, žarko in grenko) določijo srednji prag skupine. To je koncentracija, pri kateri 75% ocenjevalcev pravilno prepozna določeno lastnost. Nato preskušajo sposobnost zaznavanja prisotnosti in prepoznavanja identitete vsake od teh štirih negativnih lastnosti oljčnega olja v dvanajstih koncentracijah. Na podlagi rezultatov izberejo skupino dvanajstih najboljših kandidatov.

Naslednja faza dela izbrane skupine je usposabljanje, s katerim se povečajo individualne sposobnosti zaznavanja, prepoznavanja in vrednotenja senzoričnih lastnosti ter izboljša občutljivost in senzorični spomin. Usposabljanje poteka na številnih srečanjih ocenjevalne komisije, na katerih ob praktičnem delu z vodjem skrbno analizirajo mnenja in pripombe posameznih članov, razčistijo nejasnosti in tako poenotijo merila za nadaljnje delo. Napredek, dosežen pri usposabljanju, se statistično ovrednoti. O praktični uporabnosti takega usposabljanja so mnenja različna, velja pa, da je zelo uspešno in potrebno, če želimo, da bodo senzorični rezultati točni in natančni.

Presoja ocenjevalne komisije lahko vpliva na komercialne in tehnološke odločitve, zato je treba znanje izbranih in usposobljenih ocenjevalcev preverjati v določenih časovnih presledkih.

Senzorično ocenjevanje oljčnega olja poteka tako, da ocenjevalci ne morejo vplivati drug na drugega. Vsak ocenjevalec dela v svoji ocenjevalni kabini, katere dimenzije in opremljenost predpisuje prej omenjena metoda. Z metodo so predpisani tudi testni kozarec, temperatura in temperiranje vzorca ter postopek z oljem pri ocenjevanju. Ocenjevalec najprej olje povoha in oceni njegov vonj. Nato ga pokuša in pri tem oceni gustatorne, taktilne in kinestetične zaznave. Navodilo za postopek z oljem določa, kako in koliko časa ocenjevalec voha olje, kakšen požirek olja vzame v usta, kako razporeja olje v ustih, da zazna vse njegove okuse, in ga vzpodbuja, da opiše tudi tipne in kinestetične zaznave. Priporoča, kako odstraniti iz ust ostanke olja in predpiše čas počitka med dvema vzorcema.

Vse svoje zaznave pokuševalec analizira, ovrednoti njihovo intenziteto. Ocene se gibljejo v intervalu od 0 točk za odsotnost in 5 točk za maksimalno izraženost ocenjevalne lastnosti. Svojo oceno vpiše v ocenjevalni list. Ocenjevalni list je sestavljen iz dveh delov. V prvem so navedene najbolj pogoste senzorične zaznave in stopnje izraženosti teh zaznav, v drugem delu pa ocenjevalci ocenijo kakovost olja, tako da upoštevajo dobre in slabe lastnosti olja in mu podelijo ocene od 1 do 9, pri čemer je 1 najslabša in 9 najboljša ocena.

## OCENJEVALNI LIST

Tab. 1: *Senzorične lastnosti oljčnega olja.*  
 Tab. 1: *Sensory characteristics of olive oil.*

|   | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Oljčno sadno (zrele in zelene)                  |   |   |   |   |   |   |
| Po jabolku                                      |   |   |   |   |   |   |
| Po drugem zrelem sadju                          |   |   |   |   |   |   |
| Po zelenem (listje, trava)                      |   |   |   |   |   |   |
| Grenko  |   |   |   |   |   |   |
| Rezko (pekoče)                                  |   |   |   |   |   |   |
| Sladko  |   |   |   |   |   |   |
| Druge dovoljene lastnosti<br>(Podrobno opiši)   |   |   |   |   |   |   |
| Kislo (po vinu, po kisu, po kislem)             |   |   |   |   |   |   |
| Grobo   |   |   |   |   |   |   |
| Po kovini                                       |   |   |   |   |   |   |
| Po plesnivem, vlažnem                           |   |   |   |   |   |   |
| Po blatni usedlini                              |   |   |   |   |   |   |
| Po plesnivem (pregretem)                        |   |   |   |   |   |   |
| Žarko   |   |   |   |   |   |   |
| Druge nedovoljene lastnosti<br>(Podrobno opiši) |   |   |   |   |   |   |

Tab. 2: *Ocene napak in značilnosti oljčnega olja.*  
 Tab. 2: *Assessment of defects and characteristics of olive oil.*

| Napake                             | Značilnosti  | Celotna ocena:<br>točke |
|------------------------------------|--|-------------------------|
| Jih ni                             | Oljčno sadno   | 9                       |
|                                    | Oljčno sadno in po drugem svežem sadju                 | 8                       |
|                                    |  | 7                       |
| Šibke in komaj zaznavne            | Šibka aroma po kateremkoli sadju                       | 6                       |
| Zaznavne                           | Dokaj nečista aroma po sadju, nenavadni vonji in okusi | 5                       |
| Znatne, na meji sprejemljivosti    | Jasni, nečisti, neprijetni vonji in okusi              | 4                       |
| Mošne in/ali resne, jasno zaznavne | Za uživanje popolnoma nedopustni vonji in okusi        | 3                       |
|                                    |  | 2                       |
|                                    |  | 1                       |

Vodja ocenjevanja zbere in preveri ocenjevalne liste, iz njih oblikuje tabelo z ocenami celotne skupine in izračuna aritmetično sredino in standardni odmik od aritmetične sredine. Če vodja presodi, da je treba ocenjevanje določenega vzorca ponoviti, se ponovno ocenjevanje izvede tako, da je vzorec ocenjen v trojniku.

Olja, pri katerih je bila grenkost oz. pikantnost ocenjena z več kot 2,5 točke, označijo kot grenka ali pikantna.

Vodja na podlagi povprečne ocene uvrsti olje v ustrezno kategorijo. V poročilu je senzorična ocena

podana le z razvrstitvijo olja v kategorijo.

Iz napisanega sledi, da je senzorično ocenjevanje oljčnega olja zelo zahtevno opravilo, ki terja veliko časa in stroškov.

Da bi se izognili slabim stranem objektivnega senzoričnega ocenjevanja, so številni raziskovalci poizkušali razviti občutljivo, preprosto in zanesljivo instrumentalno metodo, ki bi dajala pravilne in ponovljive rezultate. Instrumentalne metode (GC - plinska kromatografija v kombinaciji z MS - masno spektrometrijo ali nosom kot detektorjem) zajamejo le hlapni del sestavin,

ki oblikujejo aromo olj. Če je detektor nos, lahko vonj posamezne komponente opišejo in glede na njegov pomen v aromi tudi ovrednotijo. Izkušnje kažejo, da občutljivost človekovega olfaktornega aparata večkrat prekaša občutljivost detektorjev. Tako lahko z nosom zaznajo snovi, na katere detektor ni reagiral, in včasih so prav te "manjšinske" komponente hlapnega dela

arome odločilne za tipično aromo (Kiritsakis, 1998). Ti poskusi so dali vzpodbudne rezultate. Korelacije med rezultati instrumentalne analize in senzoričnimi ocenami so dobre, vendar le človek lahko hkrati okuša, volha in integrira te svoje zaznave v aromo, česar instrument ne more.

## EVALUATION OF THE SENSORY CHARACTERISTICS OF OLIVE OILS

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### SUMMARY

*When assessing the quality of olive oils, a sensory analysis is also required apart from the chemical one. The experts believe that it is the sensory characteristics which should be in fact considered a decisive criterion in the quality of olive oils. For a faultless sensory judging, which renders repeatable results, such conditions should be ensured that are defined, controlled and repeatable at the same time, i.e.: the place of judging, samples, equipment, methods, judges and processing of results. The judges must be healthy, responsible, trustworthy and averagely sensitive people, with a good sensoric memory, and motivated for work in the sensory commission. The laboratory in which sensory analysis is carried out must be large enough, airy, suitably lit, and with comfortable and suitably equipped cabins. The samples must be representative, coded and all presented in the same way. The equipment and all other judging conditions must be selected in such a manner that can in no way affect the sensory characteristics of the judged samples.*

*The experts are of the opinion that the sensory characteristics are a decisive criterion in the quality of olive oils. The olive oils' aroma is defined as a combination of olfactory, gustatory and trigeminal senses perceived during tasting.*

*The quality of olive oils, i.e. their chemical structure and with it connected sensory characteristics, depends on numerous factors that include production, processing and storage of oils. Responsible for the oils' aroma are various volatile components, i.e. aldehydes, ketones, esters, saturated and unsaturated alcohols, and other compounds. The taste, on the other hand, is apart from the stated components created by fatty acids (particularly oil and linoleic acids) and polyphenols. Each volatile component has a characteristic smell or taste (pungent, metal, fruity, of apples, fresh, sweet, etc.), so that the oil's aroma is subject to the prevailing volatile component.*

*The sensory characteristics of olive oils are described with numerous terms relating to taste, smell and trigeminal perceptions. These are terms that are associated with foodstuffs, objects and characteristics, whose taste, smell and aroma can be perceived in oil.*

*The quality of virgin olive oils is judged according to the method prescribed by the EU Regulation No. 2568/91. The method includes a dictionary and definition of 31 expressions with which positive and negative characteristics of oils can be described. During the judging of oils the judges are not allowed to use their own idioms but only the terms from the specific sensory dictionary for olive oils. The method also regulates the selection of judges, the judging procedures and presentation of results.*

**Key words:** olive oil, sensory analysis, method



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## POLIFENOLI V OLJČNIH OLJIH SLOVENSKE ISTRE LETNIKA 94

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## IZVLEČEK

Pri 16 vzorcih oljčnih olj letnika 94 smo določili vsebnost skupnih polifenolov (pfoh) in orto difenolov (odfoh). Oboji so pomemben dejavnik pri zaščiti olja pred staranjem, saj prekinjajo avtooksidacijsko radikalsko verigo. Njihovo vsebnost smo raziskovali glede na oljne sorte šistrska belica [(pfoh) 232-327 mg/kg; (odfoh) 27-83 mg/kg], pendolino [(pfoh) 118-181 mg/kg; (odfoh) 22-35 mg/kg], leccio del corno [(pfoh) 102-224 mg/kg; (odfoh) 26-32 mg/kg], leccino [(pfoh) 121 mg/kg; (odfoh) 50 mg/kg] in glede na čas skladiščenja. Sorta istrska belica vsebuje največ polifenolov. Pri enem vzorcu pa smo s HPLC in GLC določili prisotnost posameznih vrsti polifenolov: tirosola, hidroksitirosola, 3-metoksi-4-(2-etoksi)-hidroksibenzena, 2-metoksi-4-(2-etoksi)-hidroksibenzena.

**Ključne besede:** antioksidanti, hidroksitirosol, oljčno olje, polifenoli, tirosol

## UVOD

Znano je, da ekstra deviška oljčna olja (OO) vsebujejo precej visok delež tako imenovanih "neumiljivih" sestavin. Termin "(ne)umiljiv" ima historično konotacijo: umiljive spojine so tiste, ki jih lahko umilimo, t.j. iz njih napravimo milo - soli maščobnih kislin. Le-teh je približno 0,5 do 1,5% (Kiritsakis, 1998). Trdimo lahko, da so neumiljive sestavine tiste, ki niso kemijsko povezane z maščobnimi kislinami - so tiste, ki niso olje samo (Boskou, 1996).

Pri ekstra deviških oljčnih oljih je kemijski diapazon teh spojin zelo pester - alifatski alkoholi (skvalen), tokoli ( $\alpha$ -tokoferol), steroli ( $\beta$ -sitosterol), pigmenti (klorofili, karotenoidi), hlapne spojine (trans-2-heksenal (vonj po sveže pokošeni travi)), polifenoli. Vse te spojine olja senzorično bogatijo, dajejo jim aromo - pravzaprav flavor,

t.j. vonj, okus in druge senzorične lastnosti, ki so zanj značilne (Amiot *et al.*, 1986). Še posebej zanimivi so tokoli in polifenoli, ker so antioksidanti. Antioksidanti so spojine, ki "odstranjujejo" (angl. *scavenge*) aktivne kisikove spojine in elektrofile, ki inhibirajo reakcije nitroziranja in s kovinskimi kationi tvorijo kelate (Robards & Ryan, 1998). S temi kemijskimi dejavnostmi olja varujejo pred "staranjem" (deterioracijo in razpadom triacilglicerolnih sestavin).

Termin polifenoli označuje take spojine, ki imajo na aromatskem obroču dve ali več hidroksi spojin. Sam izraz ni najbolj posrečen, saj so nekatere polifenolne učinkovine v oljčnih oljih take, da imajo samo eno hidroksilno skupino; izraz je tudi zavajajoč, saj spominja na fenole, ki so v splošni zavesti negativno označeni. V zadnjih letih se vse bolj uveljavljajo termini kot fenolne spojine, naravni fenoli in biofenoli (Bonina *et al.*, 1999).

V splošnem fenole razdelimo na flavonoide in neflavonoide. V prvem delu naše raziskave smo se ukvarjali s skupnimi polifenoli - termin označuje vse polifenolne sestavine, ki jih določimo z uporabo Folin-Ciocalteu reagenta. Žal je ta reagent pre malo specifičen, saj detektira tudi beljakovinske fenolne skupine v preiskovanem ekstraktu, motijo pa tudi reducenti kot npr. askorbinska kislina (Robards & Ryan, 1998). Poskušali smo ugotoviti morebitno korelacijo med oljčno sorto in vsebnostjo polifenolov ter vpliv staranja oljnega olja na vsebnost polifenolov.

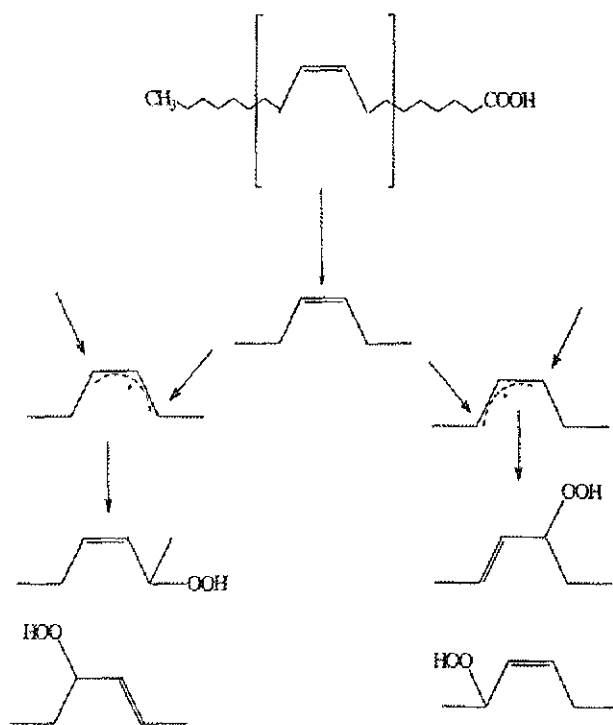
V drugem delu raziskave pa smo se ukvarjali predvsem s hidroksicimetnim in hidroksibenzojskim tipom neflavonoidnih fenolov. Tako smo na enem vzorcu OO poskušali okarakterizirati posamezne polifenole.

### PREGLED DOSEDANJIH OBJAV

Na sl. 1 je shematsko prikazana avtooksidacija oleinske kisline, ene pomembnejših maščobnih kislin v maščobnem (triacilglicerolnem) delu oljnega olja. Produkt te avtooksidacije so hidroperoksidi, relativno nestabilne spojine, ki sčasoma razpadejo do aldehydov. V primeru oleinske kisline so to oktanal, 2-decenal, 2-undecenal in nonanal - (Zelenik-Blatnik, 1995).

V primeru linolne kisline pa je nastali aldehyd heksanal. Ti aldehydi nadalje (tudi encimatsko, z alkoholnimi dehidrogenazami) zreagirajo v ustrezne alkohole, predvsem v heksan-1-ol, cis-3-heksen-1-ol in trans-2-heksen-1-ol (Giovacchino et al., 1996).

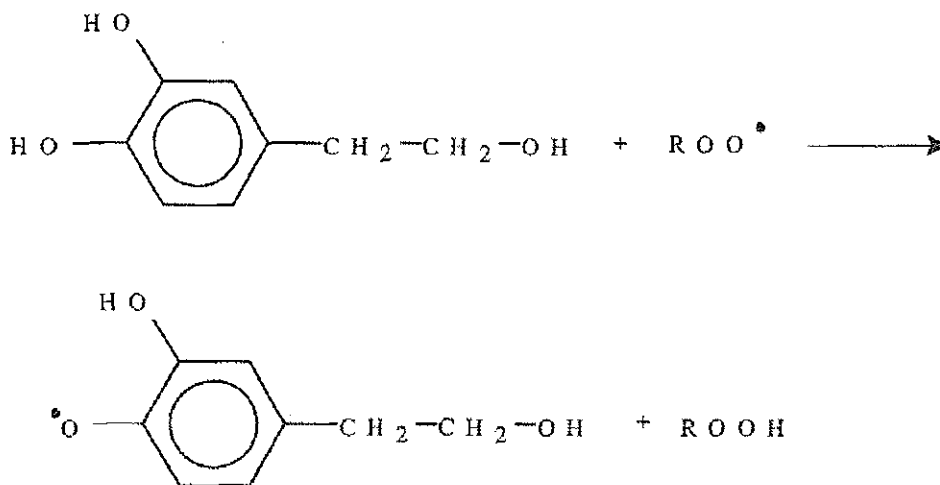
Fenoli zavirajo avtooksidacijsko pot nenasičenih kislin, npr. oleinske kisline tako, da prekinjajo avtooksidacijsko radikalno verigo s tvorbo "novih" radikalov, ko odcepijo vodik na hidroksi skupini- (Nonhebel et al., 1979; Gunstone, 1984).



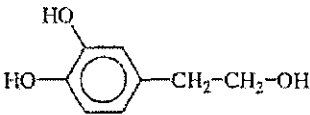
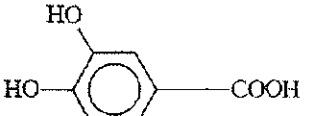
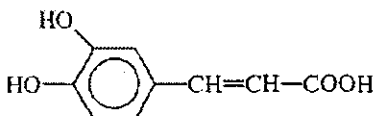
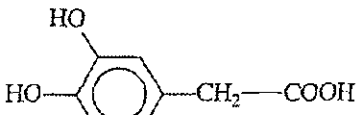
Sl. 1: Avtooksidacija oleinske kisline.  
Fig. 1: Autooxidation mechanism of oleic acid.

Znano je, da so orto polifenoli približno pet- do desetkrat močnejši antioksidati od mono polifenolov (Papadopoulos & Boskov, 1991).

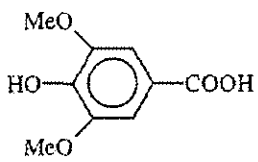
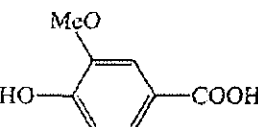
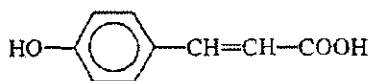
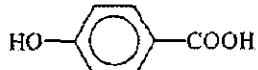
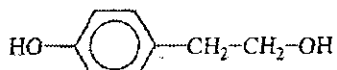
Poglejmo si polifenolne učinkovine podrobneje. Za slovensko poimenovanje nekaterih polifenolov glej Lavrenčič & Stibilj (1999). Na sl. 3 so formule nekaterih ortodifenolov, na sl. 4 pa monofenolov.



Sl. 2: Princip antioksidativnega delovanja polifenola hidroksitirosola.  
Fig. 2: The principle of the antioxidative activity of polyphenol hydroxytyrosol.

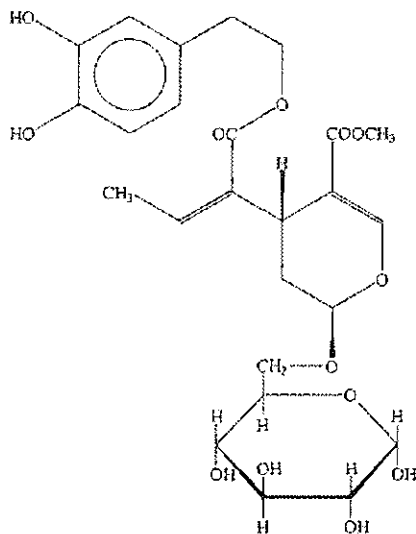
| IUPAC nomenklatura                          | Trivialno ime                      | Formula   |
|---|------------------------------------|---|
| 4-(2-hidroksi-etil)-1,2-dihidroksibenzen    | hidroksitirosol                    |  |
| 3,4-dihidroksibenzojska kislina             | protokatehujska kislina            |  |
| 3-(3,4-dihidroksifenil)-propenojska kislina | kavna kislina                      |  |
| 2-(3,4-dihidroksifenil)-etanojska kislina   | 3,4-dihidroksi fenilacetna kislina |  |

Sl. 3: Poimenovanje in formule nekaterih ortodifenolov.  
Fig. 3: Nomenclature and formulae of some orthodiphenols.

| IUPAC nomenklatura                        | Trivialno ime               | Formula   |
|---|-----------------------------|---|
| 4-hidroksi-3,5-dimetoksibenzojska kislina | siringilna kislina          |  |
| 4-hidroksi-3-metoksibenzojska kislina     | vanilinska kislina          |  |
| 3-(4-hidroksifenil)-propenojska kislina   | p-kumarna kislina           |  |
| 4-hidroksi benzojska kislina              | p-hidroksibenzojska kislina |  |
| 4-(2-hidroksi-etil)-hidroksibenzen        | tirosol                     |  |

Sl. 4: Poimenovanje in formule nekaterih monofenolov.  
Fig. 4: Nomenclature and formulae of some monophenols.

Nekateri avtorji poročajo o znatni vsebnosti glukozida oleuropeina (sl. 5) v oljčnih plodovih - (Brenes *et al.*, 1992). Oleuropein naj bi se encimatsko (*Lactobacillus plantarum*) ob pomoči  $\beta$ -glukozidaze hidroliziral v oleuropein aglikon, le-ta pa ob pomoči encima esteraza v hidroksitirosol (Marsilio *et al.*, 1996). V oljčnem olju se nahajata tudi oleuropeinu podobna fenolna glukozida verbaskozid, fenolni del v njem je kavna kislina in ligstrozid, ki je podoben oleuropeinu, fenolni del je tirosol (Boskou, 1996).



Sl. 5: Oleuropein.  
Fig. 5: Oleuropeine.

Na vsebnost polifenolov v oljčnih oljih vplivata predvsem stopnja dozorelosti oljčnih plodov (zrelejši plodovi, nižja vsebnost polifenolov) in pa način ekstrakcije. Centrifugalni postopki pridobivanja oljčnih olj oziroma vsi postopki, pri katerih je nujna uporaba velikih količin (včasih tople) vode (60-80 L/100 kg oljk), lahko znatno zdesetkajo količino polifenolov v oljih (Giovacchino *et al.*, 1994).

Polifenoli in tokoferoli oljčnih olj zavirajo hidrolizo triacilglicerolov in pa oksidacijo dvojnih vezi v triacilglicerolih. Zanimivo je, da so olja, ki so po prešanju motna zaradi emulzije oziroma disperzije, ki pri prešanjih nastane, še stabilnejša oziroma odpornejša na oksidacijo, ker je vodna faza v emulzijah še posebej bogata s polifenoli. Te emulzije se šele po nekaj mesecih ločijo v dve fazi - do takrat pa delujejo izrazito antioksidativno in "antikislinsko" - saj so poseben pufer proti naraščajoči vsebnosti prostih maščobnih kislin. Pri hidrolizi triacilglicerolov se nastajajoče proste kisline vežejo na trdne delce teh disperzij in potonejo na dno - tako zapustijo oljčno fazo in ne kvarijo arome oljčnega olja (Lercker *et al.*, 1994).

## MATERIALI IN METODE

### Material

#### Olja

Raziskavo smo opravili na 16 vzorcih OO letnika 1994, in sicer na 7 vzorcih sorte istrska belica, 4 vzorcih sorte pendolino, 3 vzorcih sorte leccio del corno in na 1 vzorcu sorte leccino. En vzorec je bil mešanica sort istrske belice in leccina.

Pri poskusu okarakterizacije polifenolov smo uporabili en vzorec OO sorte istrska belica.

Vsi vzorci so bili skladiščeni pri temperaturi 20°C, neprodušno zaprti v temne steklenice.

### Standardi

#### Skupni in orto difenoli

Za standardizacijo pri določevanju količine skupnih in o-difenolov smo uporabili Folin-Ciocalteu reagent proizvajalca Fluka Chemie AG (Buchs, Švica), kataloška številka 47641, in pa kavno kislino proizvajalca Fluka Chemie AG (Buchs, Švica), kataloška številka 60020.

#### Polifenoli za HPLC

Proizvajalec vseh uporabljenih standardov je Fluka Chemie AG (Buchs, Švica) in so naštetih po vrstnem redu eluiranja:

| standard                          | kataloška številka | konzentracija (mg/L) |
|-----------------------------------|--------------------|----------------------|
| 3,4-dihidroksifenilacetna kislina | 37860              | 10,2                 |
| tirosol                           | 56105              | 20,8                 |
| 4-hidroksibenzojska kislina       | 54630              | 20,2                 |
| 4-hidroksifenilacetna kislina     | 56140              | 20,5                 |
| vanilinska kislina                | 94770              | 20,0                 |
| kavna kislina                     | 60020              | 20,1                 |
| siringilna kislina                | 86230              | 20,2                 |
| p-kumarna kislina                 | 28200              | 21,9                 |
| o-kumarna kislina                 | 28170              | 20,6                 |

### Metode

Zaradi različne antioksidativne aktivnosti polifenolov smo pri njihovem določevanju uporabljali dve različni kemijski metodi: metodo za določevanje skupnih polifenolov (vključno z orto polifenoli) in metodo za določevanje skupnih orto difenolov (Gutfinger, 1981).

Na enem vzorcu OO sorte istrska belica pa smo poskusili kemijsko identificirati čim več polifenolnih vrst.

Iz vzorca olja smo izolirali polarno frakcijo, kot je to opisano v literaturi (Gutfinger, 1981). V tako dobljenem ekstraktu smo določili skupne polifenole, ortodifenole in posamezne vrste polifenolov.

### Ekstrakcija polifenolov

5 g olja smo raztopili v 50 mL heksana in iz tako pripravljene raztopine ekstrahirali polifenole s trikrat po 20 mL 60% vodne raztopine metanola. Pri vsaki ekstrakciji smo fazi stresali 2 minuti. Iz združenih ekstraktov smo na rotavaporju pri temperaturi 40°C odparili topilo. Sui preostanek smo rekonstituirali v 1 mL metanola in ga do analize hranili pri temperaturi -20°C.

### Določevanje skupnih polifenolov

Skupne polifenole smo določevali tako, kot je to opisano v literaturi (Gutfinger, 1981). Princip metode sloni na modro obarvanem kompleksu, ki nastane pri oksidaciji polifenolov v alkalnem mediju ob pomoči fosforvolframove (VI) in fosformolibdenove (VI) kisline (Ranalli *et al.*, 1999). 100  $\mu$ L ekstrakta smo v 10 mL merilni bučki z vodo razredčili na 5 mL. Raztopini smo dodali 500  $\mu$ L Folin-Ciocalteu reagenta. Po 3 minutah smo v bučko prilili 1 mL nasičene raztopine natrijevega karbonata (cca. 35%) ter vsebino premešali in dolili vodo do 10 mL oznake. Po 1 uri smo izmerili absorbanco pri 725E-9 m glede na slep vzorec, ki so ga sestavljali vsi omenjeni reagenti. Umeritev smo izvedli s kavno kislino v koncentracijskem območju 0-100  $\mu$ g na 10 mL raztopine. Absorbance smo določali s spektrofotometrom proizvajalca Milton Roy, model Spectronic Genesys 5.

### Določevanje orto difenolov

Orto difenole smo določali tako, kot je to opisano v literaturi (Gutfinger, 1981). Metoda sloni na rumeno obarvanem kompleksu, ki se razvije pri pH 6,5 ob prisotnosti natrijevega molibdata (VI) (Ranalli *et al.*, 1999). 200  $\mu$ L ekstrakta smo razredčili na 1 mL z vodo, dodali 1 mL fosfatnega pufru (pH 6,5) in 2 mL 5% raztopine natrijevega molibdata(VI) dihidrata. Tako pripravljeno raztopino smo premešali in po 15 minutah izmerili njeno absorbanco pri 350E-9 m glede na slepi vzorec, pripravljen enako kot testni vzorec (brez metanolnega ekstrakta). Umeritveno krivuljo smo pripravili s kavno kislino v koncentracijskem območju 0-50  $\mu$ g na 4 mL raztopine. Absorbance smo določali s spektrofotometrom proizvajalca Milton Roy, model Spectronic Genesys 5.

### Določevanje posameznih zvrsti polifenolov

Posamezne polifenole smo karakterizirali in določili s pomočjo tekočinske kromatografije visoke zmogljivosti (HPLC) na osnovi retenzijskih časov uporabljenih polifenolnih standardov in s pomočjo kapilarne plinske kromatografije (GLC) na osnovi banke podatkov masnih spektrov.

### HPLC

Uporabljali smo sistem, opremljen z gradientno črpalko, z avtoinjektorjem in UV/VIS detektorjem, model 1050, proizvajalca Hewlett Packard. Polifenole smo ločevali na koloni Hypersil ODS 5 $\mu$ m, 4.6 x 200 mm (HP). Kromatogrami so bili posneti pri 280E-9 m.

Za ločevanje smo uporabili mobilno fazo, ki je omenjena v literaturi (Andrikopoulos *et al.*, 1991), in smo jo modificirali za lastne potrebe tako, da smo dosegli čim boljše ločevanje polifenolov. Sestavljena je bila iz vode, nakisane s fosforno kislino do pH 2 (A), metanola (B) in acetonitrila (C). Pretok mobilne faze je bil 2 mL/min, čas analize pa 34 minut. Začeli smo s 100% A in ga v 12 minutah zmanjšali na 92,8%, B pa zvišali na 3% in C na 4,2%. Tako sestavo mobilne faze smo vzdrževali 7 minut, nato pa v naslednjih 15 minutah A zmanjšali na 0%, B zvišali na 41,7%, C pa na 58,3%. Do začetnih analitskih razmer smo prišli v naslednjih 5 minutah in pred naslednjim vbrizgom še 15 minut skozi kolono črpali začetno mobilno fazo. Vbrizg je bil 10  $\mu$ L metanolnega ekstrakta. Umeritev smo opravili ob pomoči omenjenih standardov v koncentracijskem območju 10-20 mg/L.

### GLC

Analize smo napravili na plinskem kromatografu proizvajalca Hewlett Packard, model HP 6890, opremljenim s *split/splitless* injektorjem, z možnostjo programiranja pretoka nosilnega plina (EPC) ter s plamensko ionizacijskim detektorjem (FID). Pri poskusu identifikacije spojin v vzorcih smo si pomagali z analizami, ki smo jih opravili na plinskem kromatografu Hewlett Packard 5890, opremljenim z masnim detektorjem.

Spojine smo ločevali na kapilarni koloni HP-5 30 m x 320  $\mu$ m x 0,25  $\mu$ m (kat. številka HP 19091-413) proizvajalca Hewlett Packard pri konstantnem pretoku dušika 1,6 mL/min (linearna hitrost 32 cm/sek). Pritisk pri začetni temperaturi peči je bil 65,2 kPa. Temperatura injektorja je bila 250°C, razmerje split pa 20:1. Temperatura peči se je od začetne 110°C s hitrostjo 10°C/min povečevala do 280°C in tako ostala še 10 minut. Vbrizg je bil 1  $\mu$ L metanolnega ekstrakta.

Spojine smo odkrivali pri temperaturi detektorja 280°C, določili pa smo jih s pomočjo površinskih deležev odgovarjajočih pikov.

### REZULTATI

V tab. 1 so zbrani podatki določevanja skupnih polifenolov (PFOH) in pa orto difenolov (ODFOH). Eksperimentalni podatki kažejo na dejstvo, da je bila vsebnost skupnih polifenolov v oljih iz sorte istrska belica znatno višja od vsebnosti le-teh v drugih oljčnih sortah in da se ta s časom znižuje. Ta razlika pri ODFOH ni tako izražena.

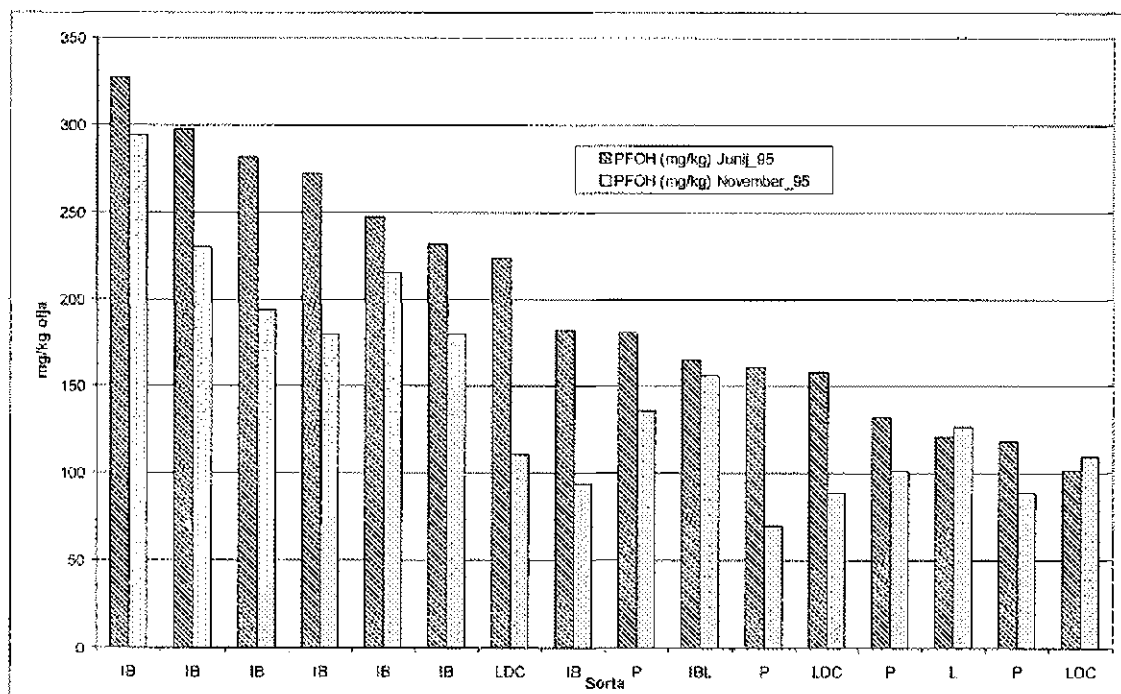
V nekaterih primerih se je vsebnost ortodifenolov s časom celo povečala. Kasnejša raziskovanja so pokazala (Butinar et al., 1999), da je to posledica pretvorbe kompleksnih polifenolov med samim skladiščenjem vzorca, saj pri tem nastane ortodifenol hidroksitirozol.

V tab. 1 sta dva časovna niza določitev: prvega smo izvedli junija 1995, drugega pa novembra 1995. Za vsak niz so predstavljene srednje vrednosti in standardni odmiki. Na sl. 6 so ti podatki grafično predstavljeni za skupne polifenole, na sl. 7 pa za ortodifenole.

Tab. 1: Količini PFOH in ODFOH v nekaterih vzorcih oljčnih olj letnika 94, določeni junija in novembra 1995.

Tab. 1: The polyphenols and orthodiphenols content in some OO samples from the 94 crop, determined in June and November 1995.

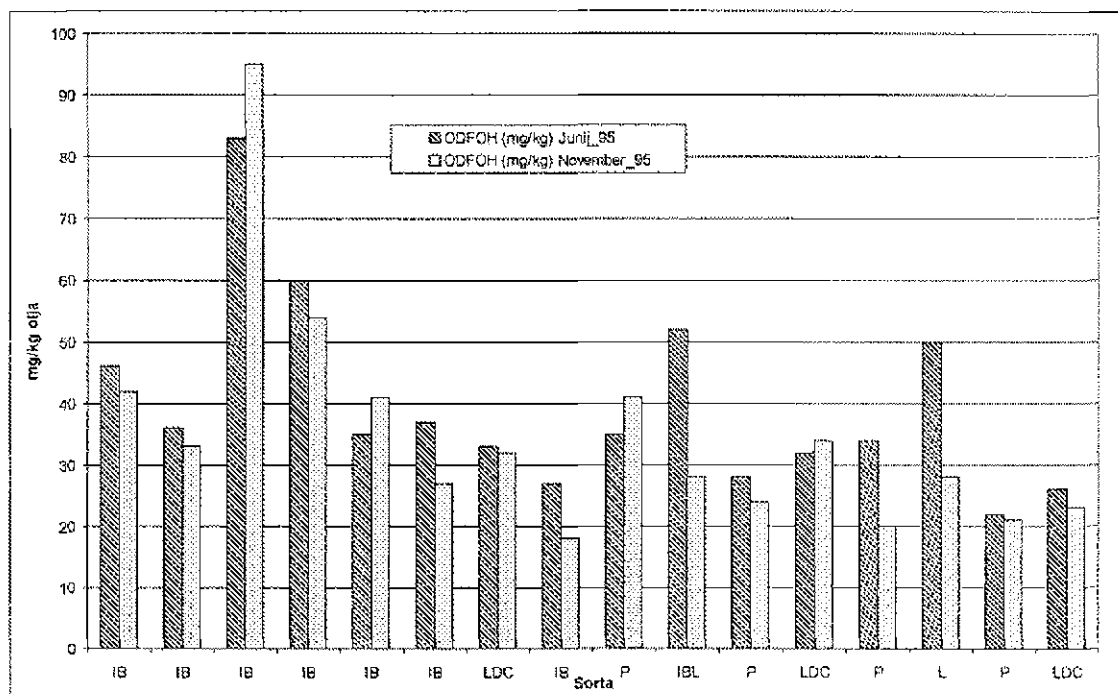
| VZOREC           | OZNAKA | PFOH (mg/kg)<br>Junij_95 | PFOH (mg/kg)<br>November_95 | ODFOH (mg/kg)<br>Junij_95 | ODFOH (mg/kg)<br>November_95 |
|------------------|--------|--------------------------|-----------------------------|---------------------------|------------------------------|
| ISTRSKA BELICA   | IB     | 327                      | 294                         | 46                        | 42                           |
| ISTRSKA BELICA   | IB     | 298                      | 230                         | 36                        | 33                           |
| ISTRSKA BELICA   | IB     | 282                      | 194                         | 83                        | 95                           |
| ISTRSKA BELICA   | IB     | 272                      | 180                         | 60                        | 54                           |
| ISTRSKA BELICA   | IB     | 247                      | 215                         | 35                        | 41                           |
| ISTRSKA BELICA   | IB     | 232                      | 180                         | 37                        | 27                           |
| LECCIO DEL CORNO | LDC    | 224                      | 111                         | 33                        | 32                           |
| ISTRSKA BELICA   | IB     | 182                      | 94                          | 27                        | 18                           |
| PENDOLINO        | P      | 181                      | 136                         | 35                        | 41                           |
| BELICA+LECCINO   | IBL    | 165                      | 156                         | 52                        | 28                           |
| PENDOLINO        | P      | 161                      | 70                          | 28                        | 24                           |
| LECCIO DEL CORNO | LDC    | 158                      | 89                          | 32                        | 34                           |
| PENDOLINO        | P      | 132                      | 101                         | 34                        | 20                           |
| LECCINO          | L      | 121                      | 127                         | 50                        | 28                           |
| PENDOLINO        | P      | 118                      | 89                          | 22                        | 21                           |
| LECCIO DEL CORNO | LDC    | 102                      | 110                         | 26                        | 23                           |
| Povprečje        | SR.V.  | 200                      | 149                         | 40                        | 35                           |
| Standardni odmik | SO     | 70                       | 62                          | 15                        | 19                           |



Sl. 6: Vsebnost polifenolov v izbranih vzorcih oljčnih olj letnika 94 (IB - sorta istrska belica, LDC - sorta leccio del corno, P - sorta pendolino, IBL - mešanica sort istrska belica in leccino, L - sorta leccino).

Fig. 6: The polyphenols content in selected OO samples from the 94 crop (IB - cv. Istrska belica, LDC - cv. Leccio del corno, P - cv. Pendolino, IBL - the mixture of cv. Istrska belica and Leccino, L - cv. Leccino).





Sl. 7: Vsebnost ortodifenolov v izbranih vzorcih oljčnih olj letnika 94 (IB - sorta istrska belica, LDC - sorta leccio del corno, P - sorta pendolino, IBL - mešanica sort istrska belica in leccino, L - sorta leccino).

Fig. 7: The orthodiphenols content in selected OO samples from the 94 crop (IB - cv. Istrska belica, LDC - cv. Leccio del corno, P - cv. Pendolino, IBL - the mixture of cv. Istrska belica and Leccino, L - cv. Leccino).

Pri identifikaciji polifenolnih zvrsti vzorca oljčnega olja sorte istrska belica ob pomoči HPLC pa smo identificirali in določili štiri glavne polifenole.

Sl. 8 prikazuje HPLC kromatogram standardne raztopine, sl. 9 pa HPLC kromatogram vzorca OO sorte istrska belica (proizvajalec Angelo Hlaj) - vbrizg je bil 10  $\mu$ L.

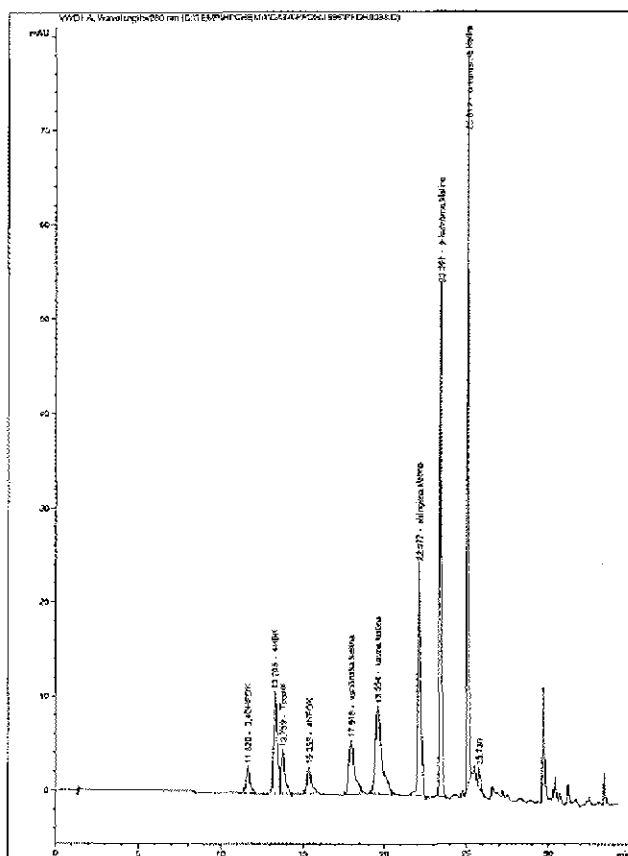
V vzorcu smo določili naslednje polifenole (v mg/kg olja): tirosol - 129,6 mg/kg, vanilinska kislina - 25,5 mg/kg, p-kumarna kislina - 17,5 mg/kg in o-kumarna kislina - 4,7 mg/kg.

Na GLC kromatogramu istega vzorca oljčnega olja, ki ga prikazujemo na sl. 10 (detektor FID), vidimo štiri identificirane polifenole, ki sestavljajo približno 28% vseh polifenolov metanolnem ekstraktu. Polifenole smo določili s FID detektorjem na osnovi površin pikov, identificirali pa s pomočjo banke masnih spektrov. To so tirosol (10%), hidroksitirosol (6%) ter 12% 3-metoksi-4-(2-etoksi)-hidroksibenzen in 2-metoksi-4-(2-etoksi)-hidroksibenzen (dva ločena pika in sicer 11% in 1% površine). Zanimivo je, da v literaturi nismo zasledili podatkov o slednjih.

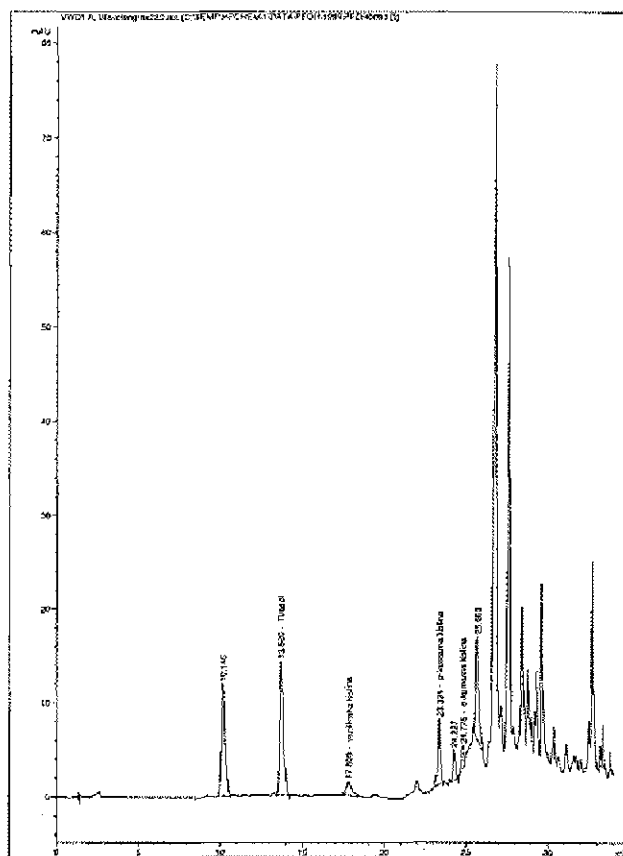
## ZAKLJUČEK

Raziskave so pokazale, da niso vsi polifenoli enako aktivni (tudi ortodifenoli ne), zato bo v prihodnje potrebno določati še neidentificirane polifenolne zvrsti na HPLC kromatogramu, ki imajo retenzijske čase med 20 in 30 minutami. Le tako bomo lahko določili posamezne relativne polifenolne deleže in njihov prispevek k skupnemu antioksidativnemu delovanju.

Podatki o vsebnosti posameznih polifenolov kot tudi podatki o vsebnosti skupnih polifenolov v oljčnih oljih slovenske Istre nam dajejo dragoceno vedenje, s pomočjo katerega bomo lahko predelovali in pridelovali olja, ki bodo še odpornejša na antioksidacijske procese. Obenem bo v prihodnje zanimivo spremljati posamezne fenolne zvrsti in njihovo relativno koncentracijo glede na sorto in leto pridelave oziroma predelave.



Sl. 8: HPLC kromatogram standardne raztopine (na abscisi je čas v minutah, na ordinati pa odgovor detektorja pri 280 HE-9 m).  
 Fig. 8: HPLC chromatogram of the standard solution (x-axis shows the analysis time and y-axis the detector response at 280 HE-9 m).

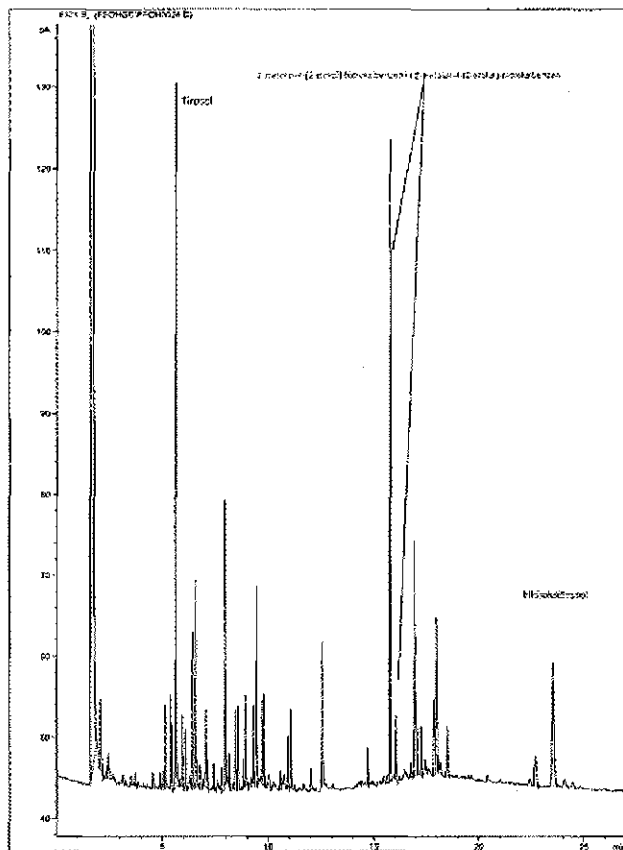


Sl. 9: HPLC kromatogram vzorca OO sorte istrska belica (na abscisi je čas v minutah, na ordinati pa odgovor detektorja pri 280 HE-9 m).  
 Fig. 9: HPLC chromatogram of an OO sample cv. Istrska belica (x-axis shows the analysis time and y-axis the detector response at 280 HE-9 m).

### ZAHVALA

Naša zahvala gre Ministrstvu za znanost in tehnologijo Republike Slovenije, Ministrstvu za kmetijstvo, gozdarstvo in prehrano Republike Slovenije, Mestni občini Koper ter Občini Izola in Piran za financiranje raziskovalnega dela. Še posebej se zahvalimo dr.

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Sl. 10: GC-FID kromatogram polarne frakcije vzorca OO sorte istrska belica (na abscisi je čas v minutah, na ordinati pa odgovor detektorja).

Fig. 10: GC-FID chromatogram of the polar fraction of OO sample cv. Istrska belica (x-axis shows the analysis time and y-axis the detector response).

## POLYPHENOLS IN OLIVE OILS FROM SLOVENE ISTRA CROP 94

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### SUMMARY

The content of total polyphenols (pfoh) and orthodiphenols (odfoh) was determined in 16 samples of olive oils crop 94. Pfoh and odfoh are an important factor in the protection of oil against ageing, for they break the autooxidant radical chain. Their content was studied in view of various olive cultivars Istrska belica [(pfoh) 232-327 mg/kg; (odfoh) 27-83 mg/kg], Pendolino [(pfoh) 118-181 mg/kg; (odfoh) 22-35 mg/kg], Leccio del corno [(pfoh) 102-224 mg/kg; (odfoh) 26-32 mg/kg], Leccino [(pfoh) 121 mg/kg; (odfoh) 50 mg/kg] and in view of the time of their storage. The cv. Istrska belica contains most polyphenols. In one sample, however, a presence of various types of polyphenols was determined with HPLC and GLC: tyrosol, hydroxytyrosol, 3-metoxy-4-(2-etoxy)-hydroxybenzene, 2-metoxy-4-(2-etoxy)-hydroxybenzene.

**Key words:** antioxidants, hydroxytyrosol, olive oil, polyphenols, tyrosol

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## SKUPNI POLIFENOLI, HIDROKSITIRO SOL IN TIROSOL V OLJČNIH OLJIH SLOVENSKE ISTRE V DVEH ZAPOREDNIH LETIH (1996, 1997)

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### IZVLEČEK

Polifenoli (PFOH) so antioksidanti rastlinskega izvora. Plodovi oljke (*Olea europaea* L.) vsebujejo PFOH, ki jih delimo v tri skupine: v iridoidne glikozide - oleuropein (OLE), verbaskozid, ligstrozid (LIG); v flavonoide ter v neflavonoidne spojine, derivate hidroksibenzojske oziroma cimetne kisline - hidroksitirosol (3,4-DHPEA) in tirosol (p-HPEA). V našem laboratoriju smo 16 vzorcem oljčnih olj (OO) letnika 1996 in 21 vzorcem OO letnika 1997 določevali skupne PFOH. Vsebnost skupnih PFOH letnika 1996 je bila med 46 in 383 mg/kg, letnika 1997 pa med 56 in 408 mg/kg.

Vzorcem OO letnika 1997 smo določili vsebnost PFOH p-HPEA (4,2-57,0 mg/kg) in 3,4-DHPEA (0,0-54,2 mg/kg). Delež vsote p-HPEA in 3,4-DHPEA se je za OO letnika 1997 v povprečju gibal med 3 in 51 odstotki skupnih PFOH.

**Ključne besede:** istrska belica, oljčno olje, oleuropein, polifenoli, iridoidni glikozidi, tirosol, hidroksitirosol

### UVOD

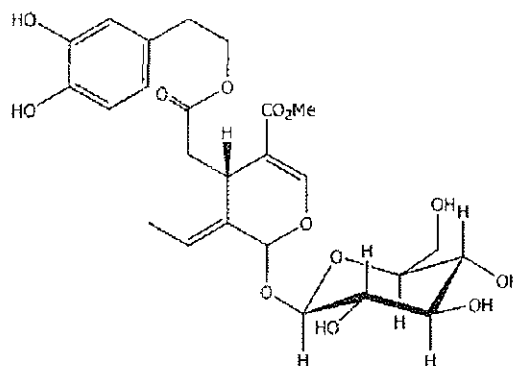
Družina fenolnih spojin, ki jo iz praktičnih razlogov imenujemo tudi polifenoli, je zelo pestra. Sestavlja dobršen del "polarne frakcije", ki jo definiramo kot segment, pridobljen pri ekstrakciji plodov ali olja z mešanico metanola in vode. Termin polifenoli pa kljub vsemu ni najbolj posrečen, saj niso vse fenolne spojine, ki sestavljajo požarno frakcijo, polihidroksilne.

Najbolj ohlapna definicija polifenolov je zato naslednja: to so rastlinske učinkovine, ki imajo na aromatskem obroču eno ali več hidroksilnih skupin. Polifenoli dajejo rastlinam barvo in okus.

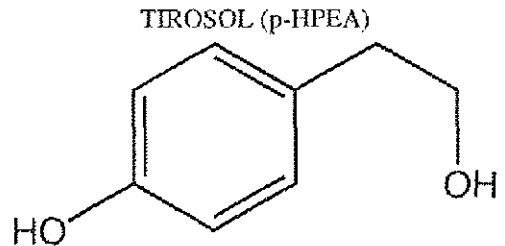
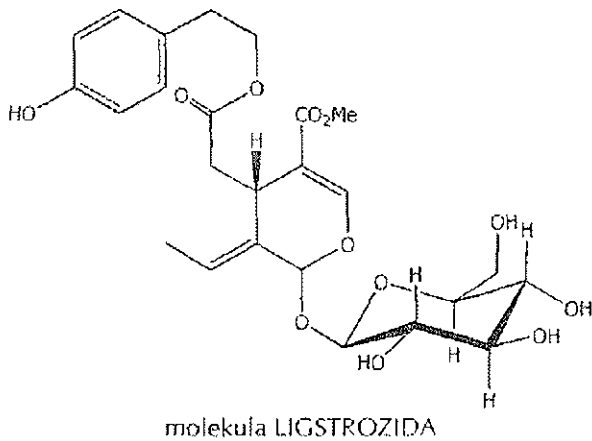
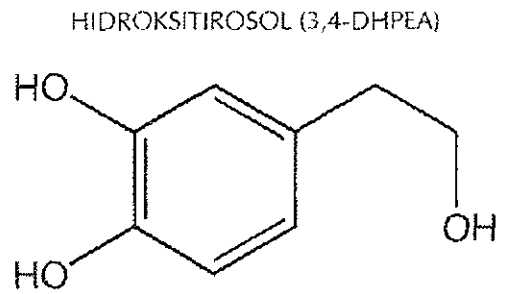
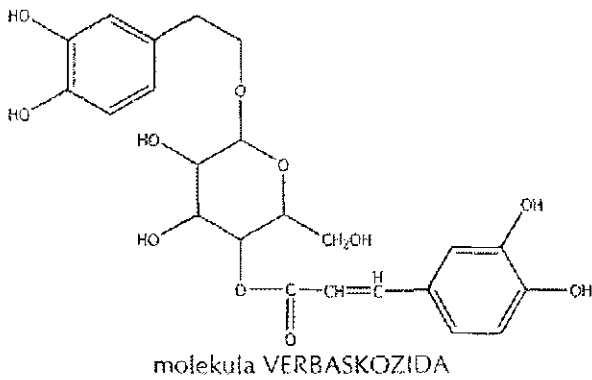
### PREGLED DOSEDANJIH OBJAV

Iz literature je poznano, da vsebujejo tako oljčni brstiči kot tudi listje in plodovi (in posledično olje) oljke (*Olea europaea* L.) (De Laurentis *et al.*, 1997) polifenole, ki jih v grobem razdelimo v tri skupine:

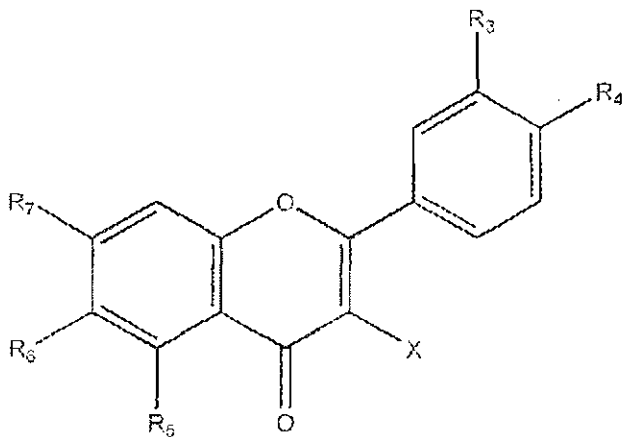
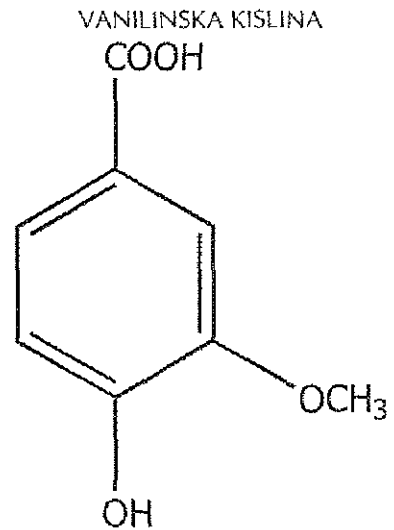
- v iridoide oziroma sekoiridoide (monoterenske laktone) - oleuropein, verbaskozid, ligstrozid, ... (Hiroshi Kuwajima *et al.*, 1988; Andary *et al.*, 1982; Gariboldi *et al.*, 1986).



molekula OLEUROPEINA (zgornji segment je fenolni, srednji kislinski, spodnji pa glukočni)

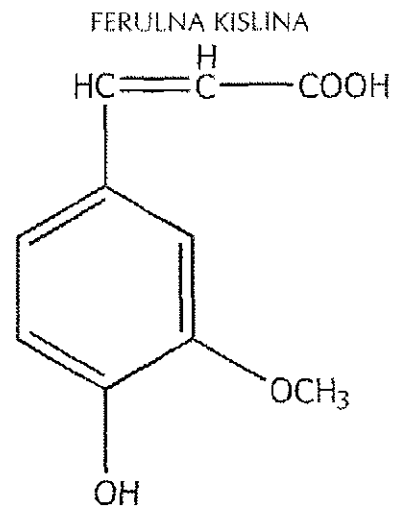


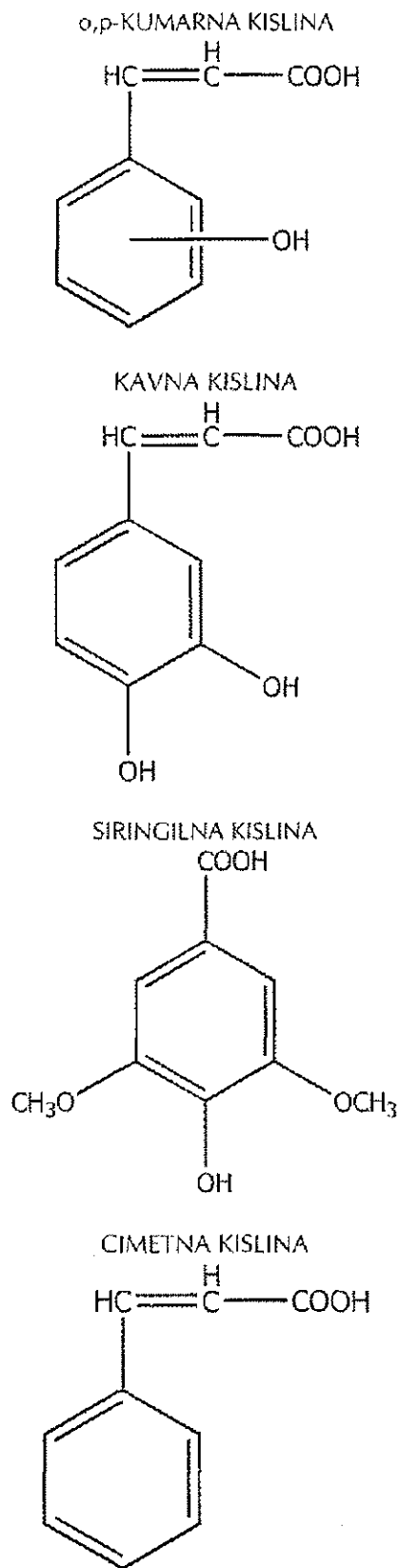
- v flavonoide (Amiot *et al.*, 1986) - apigenin, kvercetin, luteolin-7-glikozid...



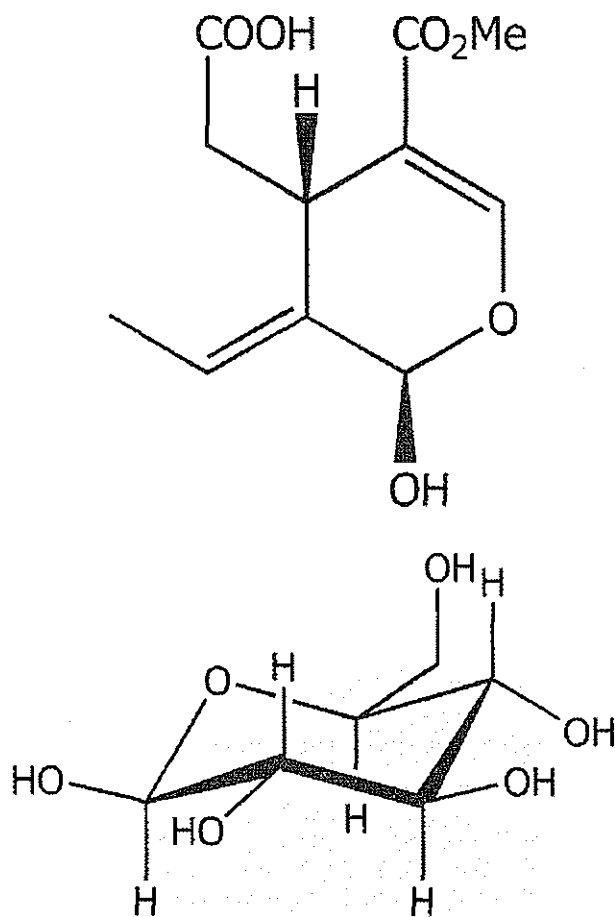
generična formula za FLAVONOIDE

- in neflavonoidne spojine, ki so predvsem derivati hidroksibenzojske oziroma cimetine kisline (e.g. hidroksitirozol, tirozol, vanilinska kislina, kavna kislina,...) - (Butinar *et al.*, 1996; Vrhovšek, 1996). Za slovensko poimenovanje nekaterih polifenolov glej Lavrenčič & Stibilj, 1999).





V zadnjih letih je pri oljčnih polifenolih težnja raziskav na sekoiridoidnih polifenolih - predvsem na oleuropeinu in na njegovih razpadnih produktih (Walter *et al.*, 1973). Oleuropein je glikozid, spojina hidroksitirosolnega estra elenolne kisline z β-D-glukopiranozo - oglejmo si ju na sl. 1.



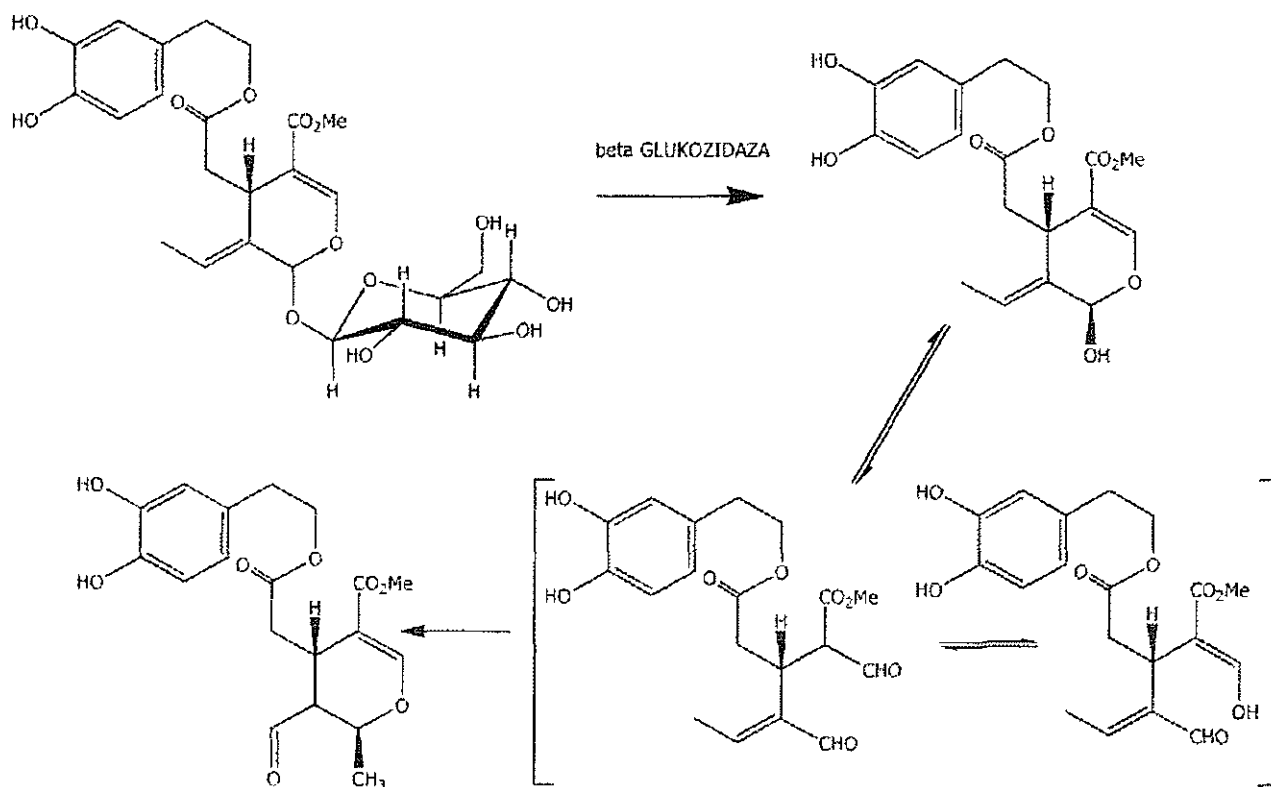
Sl. 1: Molekuli ELENOLNE KISLINE in β-D-GLUKOPIRANOZE.

Fig. 1: Molecules of ELENOLIC ACID and β-D-GLUCOPYRANOSE.

Koncentracija oleuropeina je v plodovih najvišja na prehodu pomladi v poletje, z dozorevanjem pa potekajo predvsem reakcije encimatske hidrolize - nastanek aglikona (3,4-DHPEA-EA) (Capasso *et al.*, 1996), ki kasneje prek vrste reakcij zreagira do končnih stopenj - elenolne kisline in hidroksitirosola (3,4-DHPEA) (Montedoro *et al.*, 1992a, 1992b, 1993). Podobno je pri ligstrozidu, le hidroksitirosol je v vseh stopnjah zamenjan s tirosolom (p-HPEA).

Na sl. 2 je prikazana shema encimatske hidrolize oleuropeina do oleuropein aglikona (3,4-DHPEA-EA) ter njegova izomerizacija prek dialdehidne oblike (3,4-DHPEA-EDA) oziroma (p-HPEA-EDA).





Sl. 2: Encimatska hidroliza oleuropeina do oleuropein aglikona (3,4-DHPEA-EA) ter njegova izomerizacija prek dialdehidne oblike (3,4-DHPEA-EDA) - (Marsilio et al., 1996).

Fig. 2: Enzymatic hydrolysis of oleuropeine to oleuropeine aglycone (3,4-DHPEA-EA) and its isomerisation through the dialdehydic form (3,4-DHPEA-EDA) step - (Marsilio et al., 1996).

Del raziskav oleuropeinske razpadne verige skuša tako v primeru olj kot tudi plodov te produkte analitsko ločiti, okarakterizirati in določiti njihovo vsebnost (Cinquanta et al., 1997). Ločba in ovrednotenje potekata skoraj izključno ob pomoči preparativne kromatografije visoke ločljivosti (HPLC) (Evangelisti et al., 1997). Pri karakterizaciji pa je treba uporabiti različne spektroskopske metode (NMR, UV, IR, MS) (Limiroli et al., 1995; Angerosa et al., 1995).

Tako je bilo v zadnjih letih na osnovi HPLC polarne frakcije oljčnih olj (oziroma oljk) določenih kar nekaj produktov oleuropeinske razpadne verige (Baldioli et al., 1996).

## MATERIAL IN METODE

### Material Olja

Raziskavo smo naredili na 16 vzorcih oljčnih olj letnika 1996 in na 21 vzorcih letnika 1997. Pri letniku 1996 je bila sortna sestava naslednja: istrska belica (IB) - 6 vzorcev, istrska belica cepljena na črnico (IBC) - 3 vzorci, 5 vzorcev je bilo mešanic (MIX), za 2 vzorca pa

nismo imeli podatka (BP). 4 vzorci (3 MIX in 1 IB) so bili stisnjeni iz oljk, ki so bile med trganjem in predelavo hranjene v morski vodi oziroma slanici.

Pri letniku 1997 pa: istrska belica (10 vzorcev), lecino (5 vzorcev), mešanice (6 vzorcev).

Vsi vzorci so bili skladiščeni pri temperaturi 20 °C, nepredušno zaprti v temne steklenice.

### Standardi

#### Skupni in orto difenoli

Za standardizacijo pri določevanju količine skupnih polifenolov smo uporabili Folin-Ciocalteu reagent proizvajalca Fluka Chemie AG (Buchs, Švica), kataloška številka 47641, in pa kavno kislino proizvajalca Fluka Chemie AG (Buchs, Švica), kataloška številka 60020.

#### Tirosol za HPLC

Proizvajalec standarda je Fluka Chemie AG (Buchs, Švica), njegova kataloška številka je 56105. Za umeritev smo pripravili metanolno raztopino tirosola koncentracije 420 mg/L (5 µL vbrizg).

## Metode

### Ekstrakcija polifenolov

5 g olja smo raztopili v 50 mL heksana in iz tako pripravljene raztopine ekstrahirali polifenole s trikrat po 20 mL 60% vodne raztopine metanola. Pri vsaki ekstrakciji smo fazi stresali 2 minuti. Iz združenih ekstraktov smo na rotavaporju pri temperaturi 40 °C odparili topilo. Suhi preostanek smo rekonstituirali v 1 mL metanola in ga do analize hranili pri temperaturi -20 °C.

### Določevanje skupnih polifenolov

Skupne polifenole smo določevali tako, kot je to opisano v literaturi (Gutfinger, 1981). Princip metode sloni na modro obarvanem kompleksu, ki nastane pri oksidaciji polifenolov v alkalnem mediju ob pomoči fosforvolframove (VI) in fosformolibdenove (VI) kisline (Ranalli *et al.*, 1999). 100 µL ekstrakta smo v 10 mL merilni bučki z vodo razredčili na 5 mL. Raztopini smo dodali 500 µL Folin-Ciocalteu reagenta. Po 3 minutah smo v bučko prilili 1 mL nasičene raztopine natrijevega karbonata (cca. 35%) ter vsebino premešali in dolili vodo do 10 mL oznake. Po 1 uri smo izmerili absorbanco pri 725E-9 m glede na slepi vzorec, ki so ga sestavljali vsi omenjeni reagenti. Umeritveno krivuljo smo izvedli s kavno kislino v koncentracijskem območju 0-100 µg na 10 mL raztopine. Absorbance smo izmerili s spektrofotometrom proizvajalca Milton Roy, model Spectronic Genesys 5.

### Določevanje tirosola in hidroksitirosola

Tirosol smo določili s tekočinsko kromatografijo visoke (HPLC) na osnovi retenzijskih časov uporabljenega standarda in znane umeritvene koncentracije. Hidroksitirosolnega standarda nismo našli v nobenem katalogu kemikalij, zato smo njegovo koncentracijo v vzorcih določili na osnovi literaturne primerjave retenzijskega časa in pa privzetega odgovora detektorja (response factor) za tirosol.

### HPLC

Uporabljali smo sistem, opremljen z gradientno črpalko, z avtoinjektorjem in UV/VIS detektorjem, model 1050, proizvajalca Hewlett Packard. Polifenole smo ločevali na koloni Hypersil ODS 5µm, 4.6 x 200 mm (HP). Absorbanco eluata smo merili pri 280E-9 m.

Za ločevanje smo uporabili mobilno fazo, ki je omenjena v literaturi (Brenes *et al.*, 1992). Sestavljena je bila iz vode, nakisane s fosforno kislino do pH 2 (A), in acetonitrila (B), za lastne potrebe pa smo jo modificirali tako, da smo dosegli čim boljše ločevanje polifenolov.

Pretok mobilne faze je bil 1 mL/min, čas analize pa 40 minut. Začeli smo s 95% A in 5% B. V 20 minutah smo A znižali na 75%, B pa zvišali na 25%. V naslednjih 20 minutah se je A spustil na 50%, B pa dvignil na 50%. V tej točki smo prenehali meriti absorbanco eluata. Začeli smo s čiščenjem kolone, in sicer tako, da se je v naslednjih 5 minutah A znižal na 25%, B pa dvignil na 75%. Pri taki sestavi mobilne faze smo kolono čistili 10 minut in nato v naslednji minuti vzpostavili začetno stanje (95% A in 5% B) ter stabilizirali kolono še 14 minut pred naslednjim vbrizgom. Vbrizg je bil 50 µL metanolnega ekstrakta. Umeritev smo izvedli z metanolno raztopino tirosola koncentracije 420 mg/L.

## REZULTATI

V tab. 1 so zbrani statistični podatki vsebnosti skupnih polifenolov v oljčnih oljih letnika 1996 in 1997 v mg/kg: povprečje, standardna napaka (SD), mediana, min, max, število vzorcev (n). Pri vzorcih OO letnika 1996 smo vrednosti podali samo za vzorce OO, ki niso bili stisnjeni iz oljk, hranjenih v slanici.

Tab. 1: Vsebnost polifenolov v oljčnih oljih letnikov 1996 in 1997 v mg/kg OO.

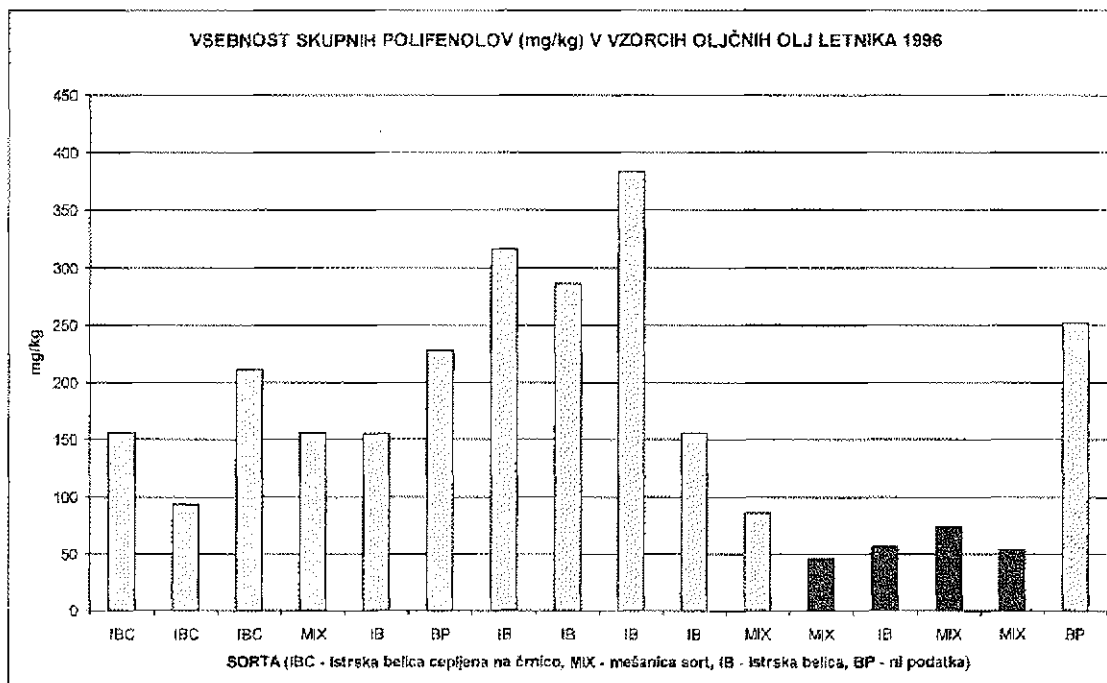
|           | letnik 1996 | letnik 1997 |
|-----------|-------------|-------------|
| Povprečje | 207         | 213         |
| SD        | 90          | 103         |
| Mediana   | 184         | 210         |
| Min       | 86          | 56          |
| Max       | 383         | 408         |
| n         | 12          | 21          |

Podatki o vsebnosti skupnih polifenolov v vzorcih ločljivosti letnika 1996 so grafično ponazorjeni na sl. 3.

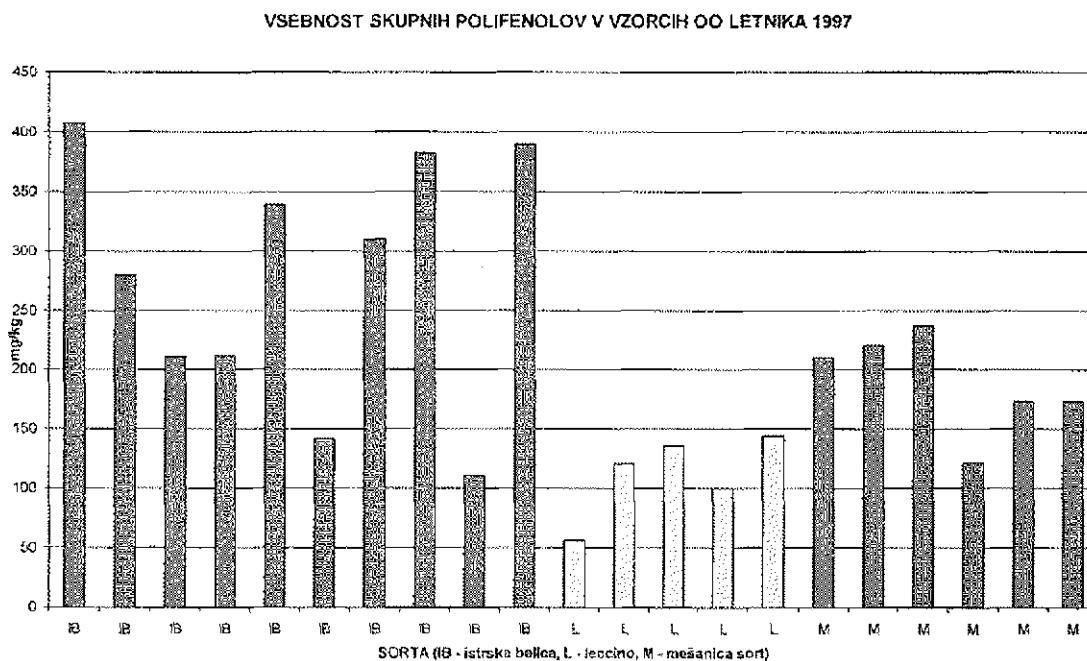
Kot smo že ugotovili v prejšnjih letih (Butinar *et al.*, 1996), so vrednosti najvišje pri vzorcih, ki so stisnjeni iz sorte istrska belica oziroma iz mešanic, kjer ima istrska belica največji delež.

Zanimive so vrednosti za vzorce, ki so označeni temno - pri teh vzorcih so bile oljke pred prešanjem hranjene v slanici oziroma morski vodi. Kljub dejstvu da je sorta istrska belica prevladujoča sorta, so vrednosti relativno nizke. Te podatke gre pripisati dejstvu, da so glavni polifenoli (oleuropein in njegovi derivati) izredno dobro topni v polarnih topilih in se zato pri daljšem skladiščenju oljk v morski vodi oziroma slanici preprosto izločijo (»izlužijo«) iz plodov. Taka olja so seveda tudi senzorično in antioksidativno revnejša.

Na sl. 4 smo prikazali vsebnost skupnih polifenolov v vzorcih oljčnih olj letnika 1997 - vzorci so razvrščeni po sortah. IB - istrska belica, L - leccino, M - mešanice dveh ali več sort.

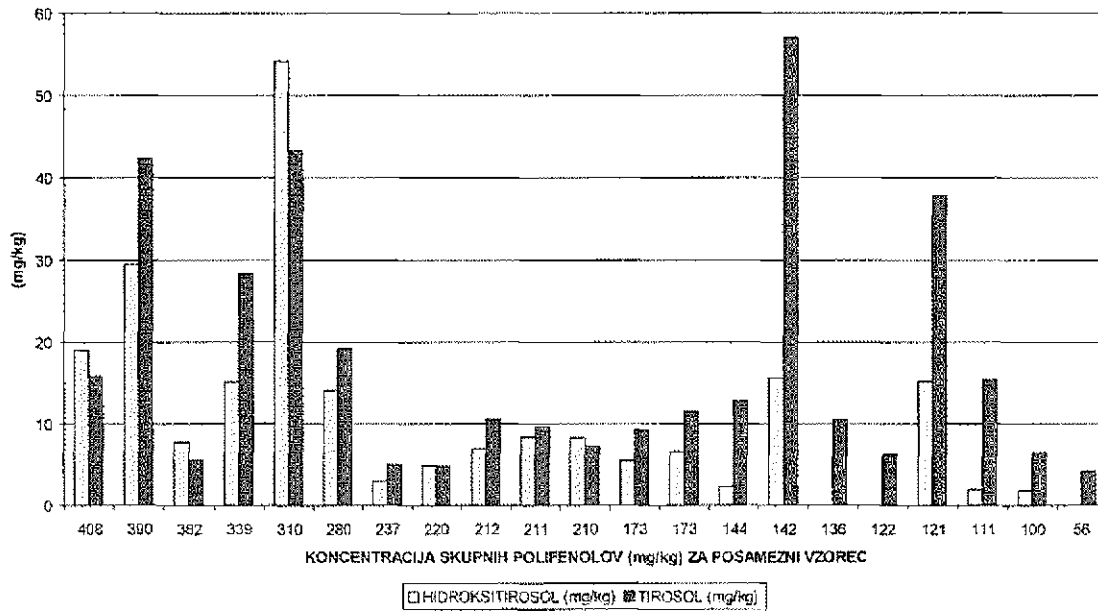


Sl. 3: Vsebnost skupnih polifenolov v vzorcih OO letnika 1996.  
 Fig. 3: Total polyphenols content in OO samples from the 1996 crop.



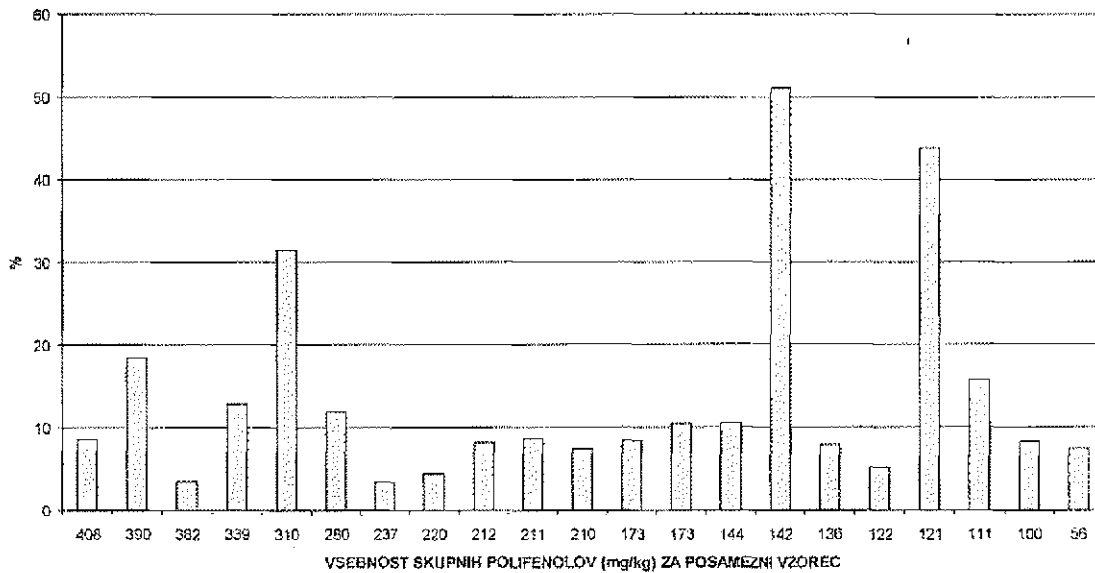
Sl. 4: Vsebnost skupnih polifenolov v vzorcih OO letnika 1997.  
 Fig. 4: Total polyphenols content in OO samples from the 1997 crop.

VSEBNOSTI HIDROKSITIROSOI IN TIROSOI V VZORCIH OLJČNIH OLJ LETNIKA 1997



Sl. 5: Vsebnost hidroksitirosoi in tirosoi v vzorcih OO letnika 1997.  
 Fig. 5: Content of hydroxytyrosol and tyrosol in OO samples from the 1997 crop.

ODSTOTNI DELEŽ VSOTE TIROSOI IN HIDROKSITIROSOI OD SKUPNIH POLIFENOLOV V OLJČNIH OLJH LETNIKA 1997



Sl. 6: Odstotni delež vsote tirosoi in hidroksitirosoi v polifenolnem delu OO letnika 1997.  
 Fig. 6: Sum of hydroxytyrosol and tyrosol vs. total polyphenols content in OO samples from the 1997 crop, in %.

Vzorci smo razdelili po sortah. Ugotovili smo, da vzorci OO, ki so stisnjeni iz sorte istrska belica, vsebujejo več polifenolov (povprečje 279 mg/kg) v primerjavi z leccinom (povprečje 111 mg/kg) oziroma mešanicami (povprečje 189 mg/kg).

Vzorcem OO letnika 1997 smo določili tudi vsebnost polifenolov tirosola in hidroksitirosola. Znano je, da je polifenol hidroksitirosol eden izmed končnih produktov razgraditve sekoiridoidnega glikozida oleuropeina. Visoke vrednosti vsebnosti hidroksitirosola ob hkratni visoki vsebnosti skupnih polifenolov kažejo na olja z bogato senzorično in z dobrimi antioksidativnimi lastnostmi.

Sl. 5 prikazuje vsebnost tirosola in hidroksitirosola za posamezne vzorce, ob hkratnem podatku za vrednost skupnih polifenolov.

Iz grafa vidimo, da je vsebnost hidroksitirosola praviloma nižja od vsebnosti tirosola. Povprečni delež obeh polifenolov je 14 odstotkov in se giblje v intervalu med 3 in 51 odstotki - sl. 6.

### ZAKLJUČEK

Pri oljčnih oljih letnika 1996 nam je uspelo zaslediti odvisnost med ekspozicijo obranih plodov v polarnih toplih (slanica, skladiščenje pred predelavo) in količino skupnih polifenolov - le-ta je nekajkrat nižja glede na plodove iste sorte, ki so bili razmeroma hitro predelani v olje. Pri vzorcih oljčnih olj letnika 1997 smo potrdili že znano dejstvo, da je oljčna sorta istrska belica tista, ki ima višjo koncentracijo skupnih polifenolov v primerjavi z drugo raziskovano sorto leccino (279 mg/kg vs. 111 mg/kg).

Pri HPLC polarne frakcije (pri 280E-9 m - sekoiridoidni segment polifenolov) nam je uspelo identificirati in določiti vsebnost dveh razpadlih produktov oleuropeina oziroma ligstrozida - tirosol in hidroksitirosol.

V prihodnje bi bilo zanimivo poskusiti identificirati in kvantizirati še preostale razpadne intermedie oleuropeina.

Iz primerjave podatkov za koncentracije skupnih polifenolov in za koncentracije tirosola ter hidroksitirosola je razvidno, da ostaja delež vsote tirosola in hidroksitirosola glede na vsoto skupnih polifenolov približno enak (s staranjem se le znižuje "zaloga" skupnih polifenolov). Pri zelo starih oziroma slabo skladiščenih vzorcih - pa tudi pri vzorcih, ki so bili pripravljene iz poškodovanih, prezrelih ali slabo skladiščenih oljk, pa se to ravnotežje zelo hitro poruši, ker encimatski razpad sekoiridoidnih polifenolov poteče že med skladiščenjem oziroma rastjo (Amiot *et al.*, 1986).

### ZAHVALA

Naša zahvala gre Ministrstvu za znanost in tehnologijo Republike Slovenije, Ministrstvu za kmetijstvo, gozdarstvo in prehrano Republike Slovenije, Mestni občini Koper ter Občini Izola in Piran za financiranje raziskovalnega dela. Dr. Vekoslavi Stibilj smo hvaležni za številne nasvete, laboratoriju LABS za nesebično pomoč pri eksperimentalnem delu, društvu DOSI za koordinacijo pri zbiranju vzorcev in pa seveda gospodu Angelu Hlaju, ki vsakič poskrbi za zlahkne vzorce OO sorte istrska belica.

## TOTAL POLYPHENOLS, HYDROXYTYROSOL AND TYROSOL IN THE OLIVE OILS OF SLOVENE ISTRA IN TWO CONSECUTIVE YEARS (1996, 1997)

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### SUMMARY

*Polyphenols (PFOH) are antioxidants of vegetable origin. Olive (Olea europaea L.) contains PFOH, which can be divided into three groups: iridoid glucosides - oleuropeine, verbascoside, ligstroside - flavonoids and non-flavonoid compounds, derivatives of hydroxybenzoic or cinnamic acid - hydroxytyrosol (3,4-DHPEA), tyrosol (p-HPEA). Oleuropeine is a glucoside, a compound of ester between 3,4-DHPEA and elenolic acid with  $\beta$ -D-glucopyranose,*

while in ligstroside the 3,4-DHPEA is replaced with *p*-HPEA. During the maturing of fruits, reactions of enzymatic hydrolysis take place - creation of aglycone, which through a series of reactions turns to elenolic acid and 3,4-DHPEA or *p*-HPEA. These products can be separated with gradient HPLC. In our laboratory we recorded HPLC chromatograms of polar fraction in 21 samples of olive oils (OO) from the 1997 crop and determined the content of *p*-HPEA (4.2-57.0 mg/kg) and 3,4-DHPEA (0.0-54.2 mg/kg). The high values of the 3,4-DHPEA content and at the same time the high content of total PFOHs indicate oils with rich sensorics and good antioxidative characteristics. Total PFOHs were also determined in OO, i.e. in 16 samples from the 1996 crop (46-383 mg/kg) and 21 samples from the 1997 crop (56-408 mg/kg). The highest values were recorded in those OO samples that had been pressed out of the cv. "Istrska belica" or the blends in which "Istrska belica" had the highest share. An exception were the values of some 1996 OO, the olives of which had been prior to the processing kept in saline water (46-74 mg/kg). Such OO are of course also sensorically and antioxidatively poorer.

**Key words:** hydroxytyrosol, iridoid glucosides, oleuropein, olive oil, polyphenols, tyrosol

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## TOKOFEROLI V OLJČNIH OLJIH SLOVENSKE ISTRE V TREH ZAPOREDNIH LETIH

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### IZVLEČEK

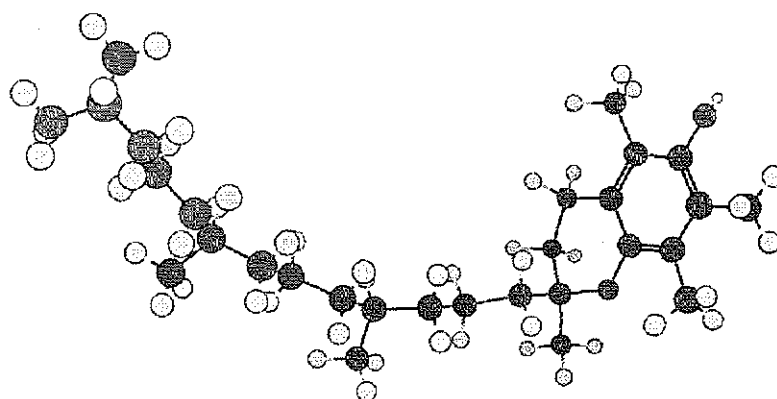
Antioksidanti so spojine, ki oljčna olja (OO) varujejo pred staranjem. Vitamin E je antioksidant, ki se predvsem v obliki  $\alpha$ -tokoferola pojavlja v ekstra deviških OO. Rezultati analiz vsebnosti skupnih tokoferolov (ST) v OO slovenske Istre (letniki 1995, 1996 in 1997) so 3,18 mg/100 g; 6,73 mg/100 g in 4,09 mg/100 g. Pri treh vzorcih OO letnika 1995, pri katerih smo raziskovali vpliv neustreznega skladiščenja na vsebnost ST, je vsebnost le-teh padla pod 1 mg/100 g.

**Ključne besede:** antioksidanti, hidroksitirosof, oljčno olje, polifenoli, tirosof

#### UVOD

Znano je, da ekstra deviška oljčna olja vsebujejo precej visok delež tako imenovanih neumiljivih sestavin, takih, ki ne spadajo k triacilglicerolom. Vse te spojine olja senzorično bogatijo - dajejo jim aromo. Še posebej zanimivi so vitamin E in (poli)fenoli, saj so le-ti antioksidanti, spojine torej, ki olje varujejo pred "sta-

ranjem" (deterioracijo in razpadom). Olje je zaščiteno pred oksidacijo vse dotlej, dokler je v njem še kaj antioksidantov. Najvažnejši dejavnik, ki vpliva na vsebnost vitamina E, je prav gotova sorta, potem pa sledijo klimatske razmere v času dozorevanja plodov ter seveda način predelave in skladiščenja. Na sl. 1 je kemijska formula homologa vitamina E,  $\alpha$ -tokoferola.

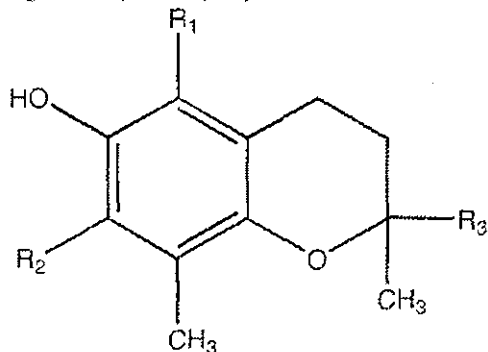


Sl. 1: 3D kemijska formula homologa vitamina E  $\alpha$ -tokoferola.  
Fig. 1: 3D structural formula of a homologue of vitamin E  $\alpha$ -tocopherol.

**PREGLED DOSEDANJIH OBJAV**

Poznanih je osem naravnih substanc, ki jih generično imenujemo vitamin E. Kemijsko jih delimo v skupini tokotrienolov in tokoferolov. Tokoferoli in tokotrienoli (s skupnim imenom tokoli) so visokomolekularni ciklični alkoholi.

Tokoferoli in tokotrienoli združujejo  $\alpha$ ,  $\beta$ ,  $\gamma$  in  $\delta$  homologe. Sl. 2 prikazuje njihove strukture.



| TOKOFEROLI           | R <sub>1</sub>  | R <sub>2</sub>  | R <sub>3</sub>  |
|----------------------|-----------------|-----------------|---|
| $\alpha$ - tokoferol | CH <sub>3</sub> | CH <sub>3</sub> | CH <sub>2</sub> [CH <sub>2</sub> CH <sub>2</sub> CH(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\beta$ - tokoferol  | CH <sub>3</sub> | H               | CH <sub>2</sub> [CH <sub>2</sub> CH <sub>2</sub> CH(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\gamma$ - tokoferol | H               | CH <sub>3</sub> | CH <sub>2</sub> [CH <sub>2</sub> CH <sub>2</sub> CH(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\delta$ - tokoferol | H               | H               | CH <sub>2</sub> [CH <sub>2</sub> CH <sub>2</sub> CH(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |

| TOKOTRIENOLI           | R <sub>1</sub>  | R <sub>2</sub>  | R <sub>3</sub>  |
|------------------------|-----------------|-----------------|---|
| $\alpha$ - tokotrienol | CH <sub>3</sub> | CH <sub>3</sub> | CH <sub>2</sub> [CH <sub>2</sub> CH=C(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\beta$ - tokotrienol  | CH <sub>3</sub> | H               | CH <sub>2</sub> [CH <sub>2</sub> CH=C(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\gamma$ - tokotrienol | H               | CH <sub>3</sub> | CH <sub>2</sub> [CH <sub>2</sub> CH=C(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |
| $\delta$ - tokotrienol | H               | H               | CH <sub>2</sub> [CH <sub>2</sub> CH=C(CH <sub>3</sub> )CH <sub>2</sub> ] <sub>3</sub> H |

Sl. 2: Strukture tokolov (Shukla et al., 1997; White & Xing, 1997).

Fig. 2: Structures of tocols (Shukla et al., 1997; White & Xing, 1997).

Tokoli so bogato zastopani v rastlinskih tkivih, predvsem v orehih in lešnikih, rastlinskih oljih, sadju in zelenjavi. Še posebej veliko jih je v pšeničnih kalčkih, koruzi, sončničnem semenu, semenu ogrščice, sojinem olju, v črni detelji in v solati. Oljčna olja se po vsebnosti vitamina E uvrščajo na sredino lestvice rastlinskih olj.

Antioksidativna aktivnost tokolov je odvisna od geometrije molekule (vrste in števila substituent (e.g. R<sub>1</sub>, R<sub>2</sub> in R<sub>3</sub>)) in od temperature. Pri temperaturi 37°C je antioksidativna moč naslednja:  $\alpha > \beta > \gamma > \delta$ . Pri povišanih temperaturah (50-100°C) pa se antioksidativna moč obrne:  $\alpha > \beta > \gamma$ .  $\delta$  tokoferol je biološko daleč najbolj zastopan tokolni homolog - njegova biološka aktivnost je dvakrat večja od  $\beta$  in  $\delta$  homologov ter 100 krat večja od  $\gamma$  homologa (Madhavi et al., 1996).

Omenili smo, da tokoli olja varujejo pred staranjem - pred razpadom in deterioracijo. Eden izmed glavnih razlogov za deterioracijo olja sta encimatski in oksidacijski proces. Tokoli preprečujejo oksidacijo olj in lipidnih sestavin v živilih tako, da kot antioksidanti preprečujejo avtooksidacijo in fotooksidacijo.

**Avtooksidacija**

Avtooksidacija je vrsta radikalne substitucijske reakcije, ki je shematsko ponazorjena na sl. 3.

|  |   |
|--|---|
| $LH \rightarrow L^\bullet$   | INICIACIJA (nastanek prostega radikala) |
| $L^\bullet + O_2 \rightarrow LO_2^\bullet$                                     | REAKCIJA RADIKALA S KISIKOM             |
| $LO_2^\bullet + LH \rightarrow L^\bullet + LOOH$                               | PROPAGACIJA                             |
| $LO_2^\bullet + E \rightarrow E^\bullet + LOOH$                                | REAKCIJA Z ANTIOKSIDANTOM               |
| $E^\bullet + E^\bullet \rightarrow E-E; L^\bullet + L^\bullet \rightarrow L-L$ | TERMINACIJA                             |

LH - maščobna kislina, L<sup>•</sup> - maščobnokislinski radikal, LO<sub>2</sub><sup>•</sup> - peroksi radikal, E - tokoferol, LOOH - hidroperoksid

Sl. 3: Radikalni mehanizem avtooksidacijske reakcije v oljih (Deshpande et al., 1996).

Fig. 3: Radical reaction mechanism of the autooxidation reaction in oils (Deshpande et al., 1996).

V živih tkivih - v celičnih membranah - pa avtooksidacijsko verigo tvori še regeneracijska stopnja tokoferola (Deshpande et al., 1996):

|   | REGENERACIJA               |
|---|----------------------------|
| $E^\bullet + C \rightarrow E + C^\bullet$ | C - askorbinska kislina    |
| $C^\bullet + NADPH \rightarrow C + NADP$  | GSH - reducirani glutation |
| $E^\bullet + 2GSH \rightarrow E + GSSG$   | GSSG - glutation disulfid  |
| $GSSG + NADPH \rightarrow NADP + 2GSH$    |                            |

Hitrost reakcije avtooksidacije in podrobna struktura nastalih hidroperoksidov sta v veliki meri odvisna od resonančno stabiliziranega alilnega radikala L<sup>•</sup>, ki nastane iz nenasičene kisline LH.

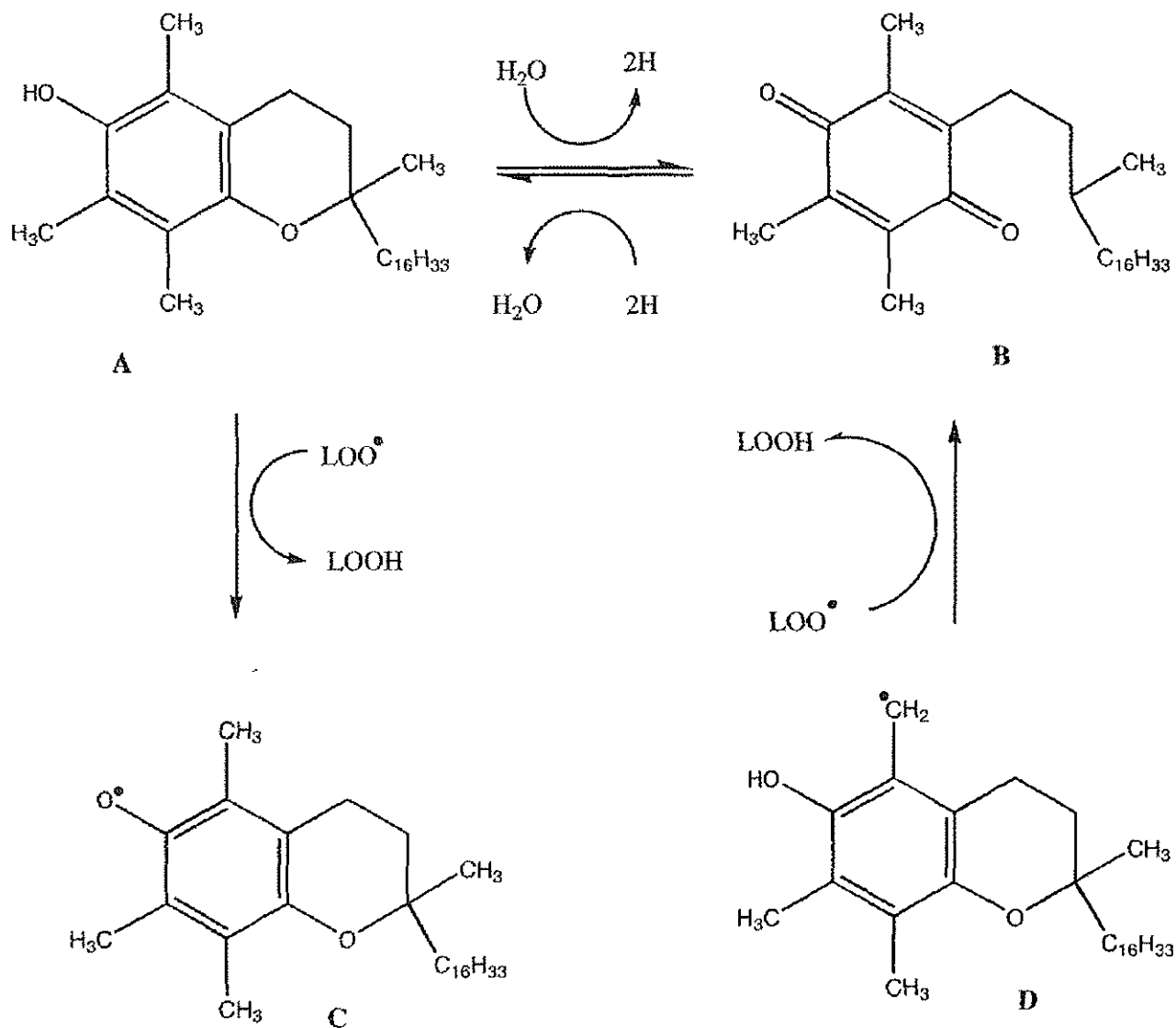
Podrobna geneza inicializacijskega koraka še ni popolnoma pojasnjena, čeprav je znano, da ga favorizirajo ustrezni radikali, e.g. taki, ki nastajajo s kovinsko kataliziranim razpadom predhodno nastalih hidroperoksidov.

Predhodno nastali hidroperoksidi so lahko produkt te iste avtooksidacije oziroma so nastali s fotooksidacijo, ki pa jo favorizirajo sledovi pigmentov v olju, npr. klorofil. Vidimo torej, da lahko reakcijo avtooksidacije

znatno zavremo, če poskrbimo, da je koncentracija kovin, v glavnem železa in bakra, minimalna.

Antioksidanti pa lahko preprečujejo reakcijo avto-oksிடacije tako, da favorizirajo radikalne terminacijske procese in s tem seveda skrajšujejo propagacijske

procesе, oziroma tako, da z LH tekmujejo za reakcijo z  $LO_2^\bullet$ , pri čemer se tvori veliko bolj stabilni LOOH (Cuppett et al., 1997). Ta proces ponazarjajo reakcije s sl. 4.



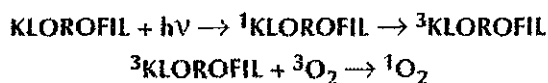
Sl. 4: Oksidacija  $\alpha$ -tokoferola (A) v  $\alpha$ -tokoferil kinon (B) prek semikinonskih intermediatov (C, D) (Cuppett et al., 1997).

Fig. 4:  $\alpha$ -tocopherol (A) oxidation to  $\alpha$ -tocopheryl quinone (B) through semiquinone intermediates (C, D) (Cuppett et al., 1997).

### Fotooksigenacija

Pogoj za fotooksidacijo je singletni kisik, ki nastane v reakciji iz tripletnega kisika s pomočjo svetlobe in ustreznе spojine (angl. *sensitizer*), ki je v primeru oljčnih

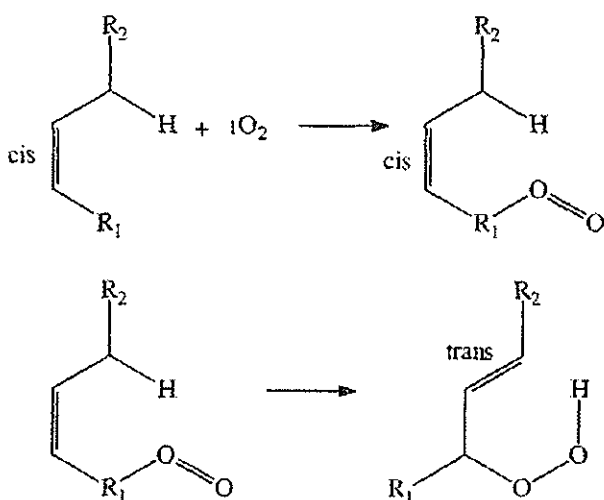
olj klorofil. Jasno je, da ta reakcija uspešno poteče le, če je na voljo svetloba, predsem svetloba z valovno dolžino iz ultravijoličnega dela spektra (UV). Omenjena reakcija je prikazana na sl. 5.



Sl. 5: Shematski prikaz reakcije, pri kateri iz tripletnega kisika in klorofila s pomočjo svetlobe nastane singletni kisik.

Fig. 5: Schematic reaction showing the formation of the singlet oxygen from the triplet oxygen and chlorophyll in the presence of the UV light.

Tako nastali singletni kisik se adira na olefinski del nenasičene maščobne kisline, v nadaljevanju pride do premestitve dvojne vezi in do spremembe konfiguracije na dvojni vezi iz *cis* v *trans*. Ta mehanizem je prikazan na sl. 6.



Sl. 6: Reakcija fotooksidacije.  
Fig. 6: The photooxygenation reaction.

Na hitrost reakcije fotooksidacije v nasprotju z avtooksidacijo ne vplivajo antioksidanti, znatno pa jo zmanjšujejo preprečevalci nastajanja singletnega kisika (angl. *radical quencher*), e.g. karoteni in tudi tokoli - v oljčnem olju je tetraterpen  $\beta$  karoten (sl. 7).

Reakcija fotooksidacije je znatno hitrejša od reakcije avtooksidacije. V tab. 1 so navedene relativne

reakcijske hitrosti avtooksidacije in fotooksidacije za kisline C 18:1 (*cis*-9), C 18:2 (*cis* 9,12) in C 18:3 (*cis*-9,12,15), ki so pomembnejše nenasičene kisline v oljčnem olju.

Tab. 1: Relativne reakcijske hitrosti oksidacij za pomembnejše nenasičene maščobne kisline OO (Gunstone, 1984).

Tab. 1: Relative oxydation reaction rates for the main unsaturated fatty acids of olive oils (Gunstone, 1984).

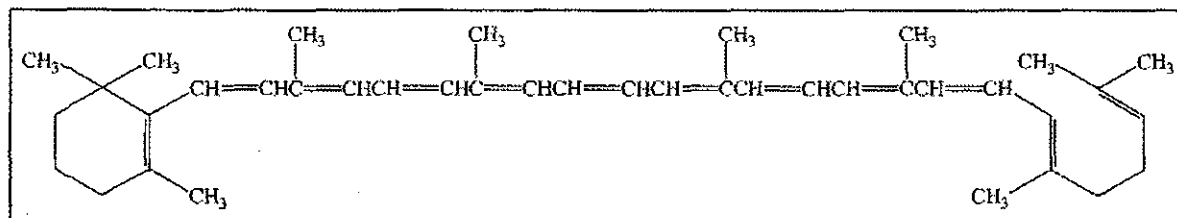
| PROCES         | MAŠČOBNE KISLINE |        |        |
|----------------|------------------|--------|--------|
|                | C 18:1           | C 18:2 | C 18:3 |
| AVTOOKSIDACIJA | 1                | 27     | 77     |
| FOTOOKSIDACIJA | 3E4              | 4E4    | 7E4    |

Reakcijski poti avtooksidacije in fotooksidacije sta različni, njuni reakcijski hitrosti sta tudi različni - in seveda dajeta tudi različne produkte. Poglejmo si vse hidroperokside, ki nastanejo po obeh reakcijskih poteh iz oleinske kisline C 18:1 (*cis*-9). Reakcija avtooksidacije da štiri različne hidroperokside, reakcija fotooksidacije pa dva (Bučar-Miklavčič *et al.*, 1995a in b). Sl. 8 in sl. 9.

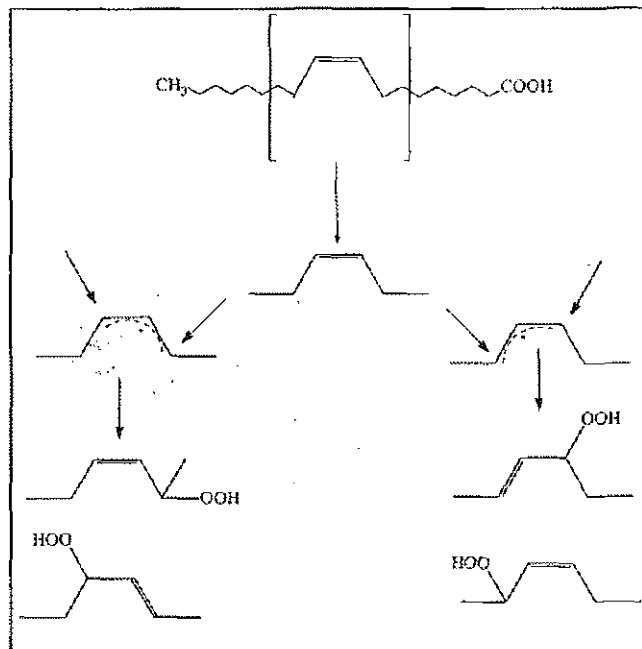
Oljčna olja vsebujejo od 5 do 300 mg/kg celokupnih tokoferolov, od tega je cca. 95%  $\alpha$  - tokoferola in 5%  $\beta$  in  $\gamma$  - tokoferola.  $\delta$  tokoferol se v oljčnih oljih pojavlja samo v sledih, in sicer v koncentracijah od 0,2 mg - 2 mg/kg (Boskou, 1996).

Zanimivo je, da večina semenskih olj vsebuje znatno višje koncentracije  $\gamma$  tokoferola kot pa  $\alpha$  tokoferola (e.g. sojino olje, koruzno olje, bučno olje) - (Madhavi *et al.*, 1996). To dejstvo lahko tudi izkoristimo pri analitskem določevanju adulteracije oljčnih olj s semenskimi (Kiritsakis, 1998).

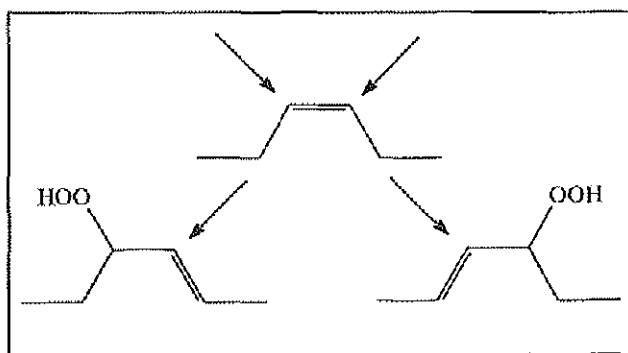
Vsebnost tokoferolov v oljčnih oljih je odvisna od sorte, klimatskih razmer v času dozorevanja, časa in načina predelave ter skladiščenja. Olja iz zgodaj obranih in predelelih plodov imajo znatno višje vsebnosti tokoferolov. Kakovostna olja vsebujejo od 100-300 mg/kg tokoferolov (Cimato *et al.*, 1992), medtem ko imajo olja z visoko vsebnostjo prostih maščobnih kislin nizko vsebnost tokoferolov (Bučar-Miklavčič *et al.*, 1995b).



Sl. 7:  $\beta$ -karoten.  
Fig. 7:  $\beta$ -carotene.



Sl. 8: Produkti avtooksidacije oleinske kisline.  
Fig. 8: The products of the autooxidation of oleic acid.



Sl. 9: Produkti fotooksidacije oleinske kisline.  
Fig. 9: The products of the photooxygenation of oleic acid.

MATERIAL IN METODE

Material

Oljčna olja

Prvi del raziskave smo opravili na 24 vzorcih OO letnika 1995, določitev november 1996; na 27 vzorcih OO letnika 1996, določitev maj 1997 ter na 30 vzorcih OO letnika 1997, določitev maj 1998. Vsa OO so bila do analize skladiščena v temi, v neprodušno zaprtih temnih steklenicah brez zračne atmosfere nad oljem, pri temperaturi 15°C.

Pri drugem delu raziskave pa smo na populaciji 5

vzorcev OO letnika 1995 določili koncentracijo tokoferolov takoj po predelavi (december 1995) in pa po 6 mesecih namerno izbranega neustreznega skladiščenja (prozorne steklenice, neposredna svetloba, sobna temperatura). Izbrani vzorci so bili naslednji: MEŠANICA NOV. 95 (mešanica OO, ki so bila predelana novembra 1995), VISOKO KŠ (mešanica OO z visoko vsebnostjo prostih maščobnih kislin takoj po predelavi), MEŠANICA DEC. 95 (mešanica OO, ki so bila predelana decembra 1995), MEŠANICA SLANICA (mešanica OO, ki so bila predelana iz plodov, ki so bili pred predelavo hranjeni v slanici) ter OO IB (vzorec OO sorte istrska belica).

Standardi

Pri karakterizaciji in določevanju koncentracije tokoferolov smo uporabili standarde prizvajalca Merck (Darmstadt, Nemčija). Pripravili smo umeritveno mešanico naslednjih koncentracij:

| tokoferol     | koncentracija (ng/μL) |
|---------------|-----------------------|
| α - tokoferol | 5,1                   |
| β - tokoferol | 6,1                   |
| γ - tokoferol | 6,0                   |
| δ - tokoferol | 5,5                   |

Koncentracijo pripravljenih standardov smo preverili po A.O.C.S. metodi Ce 8-89 (AOCS, 1990; Balz *et al.*, 1996).

Metode

Priprava vzorcev

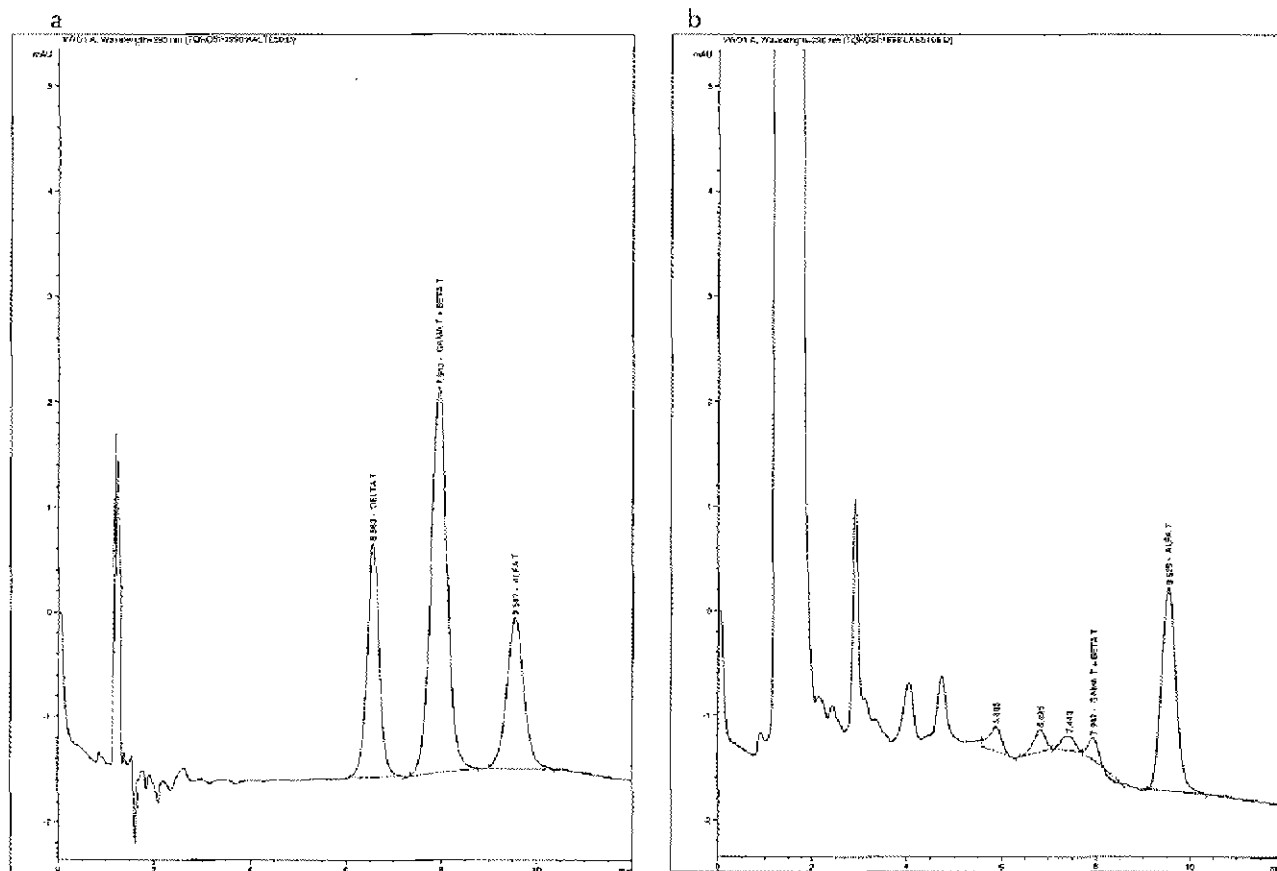
300 do 500 mg vzorca OO smo natehtali v 4 mL vialo in dodali 3,0 mL metanola. Vialo smo dobro premešali in stresali oziroma ekstrahirali na supersonični kopeli 15 minut. Po končani ekstrakciji smo iz ločene polarne faze odpipetirali cca. 1 mL metanolne raztopine in jo prenesli v temno 2 mL vialo HPLC avtoinjektorja.

Oprema

Vsebnost tokoferolov smo določevali s pomočjo tekočinske kromatografije visoke ločljivosti (HPLC) na osnovi retenzijskih časov in koncentracije uporabljene standarda.

HPLC

Uporabljali smo sistem, opremljen z gradientno črpalko, z avtoinjektorjem in UV/VIS detektorjem, model 1050, proizvajalca Hewlett Packard. Tokoferole smo ločevali na koloni Hypersil ODS 5μm, 4.6 x 200 mm (HP). Absorbanco eluata smo merili pri 290E-9 m.



Sl. 10: HPLC kromatogram standardne mešanice tokoferolov (a) in pa vzorca OO letnika 1997 (b).  
 Fig. 10: HPLC chromatogram of the standard mixture of tocopherols (a) and of OO sample from the 1997 crop (b).

Za ločevanje smo uporabili mobilno fazo, sestavljeno iz vode (92%) in metanola (8%). Pretok mobilne faze je bil 2 mL/min, čas analize pa 12 minut.

Vbrizg je bil 50 µL metanolnega ekstrakta. Omenjeni kromatografski sistem ne ločuje med β in γ tokoferolno izomero, a smo se vendarle odločili zanj, saj sta njuni koncentraciji v OO znatno nižji od koncentracije α-tokoferola. Pri umeritvi smo upoštevali vsoto obeh izomer.

Na sl. 10 sta HPLC kromatograma standardne mešanice in pa vzorca OO letnika 1997.

**REZULTATI**

Rezultati določitev vsebnosti skupnih tokoferolov za OO letnikov 1995, 1996 in 1997 so zbrani v tab. 2 (v mg skupnih tokoferolov/100 g OO).

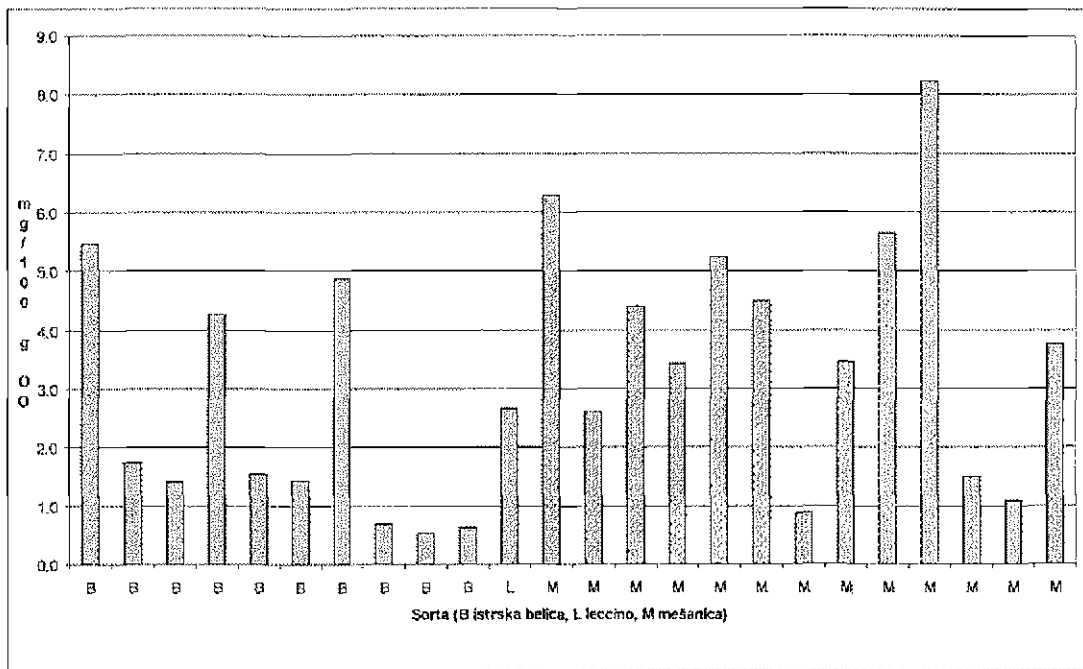
V drugem nizu eksperimentalnih podatkov pa so prikazane vrednosti za vsebnost skupnih tokoferolov v izbranih vzorcih OO letnika 1995, pri katerih smo raziskovali vpliv staranja v razmerah neustreznega skladiščenja na količino skupnih tokoferolov.

Rezultate si oglejmo v tab. 3.

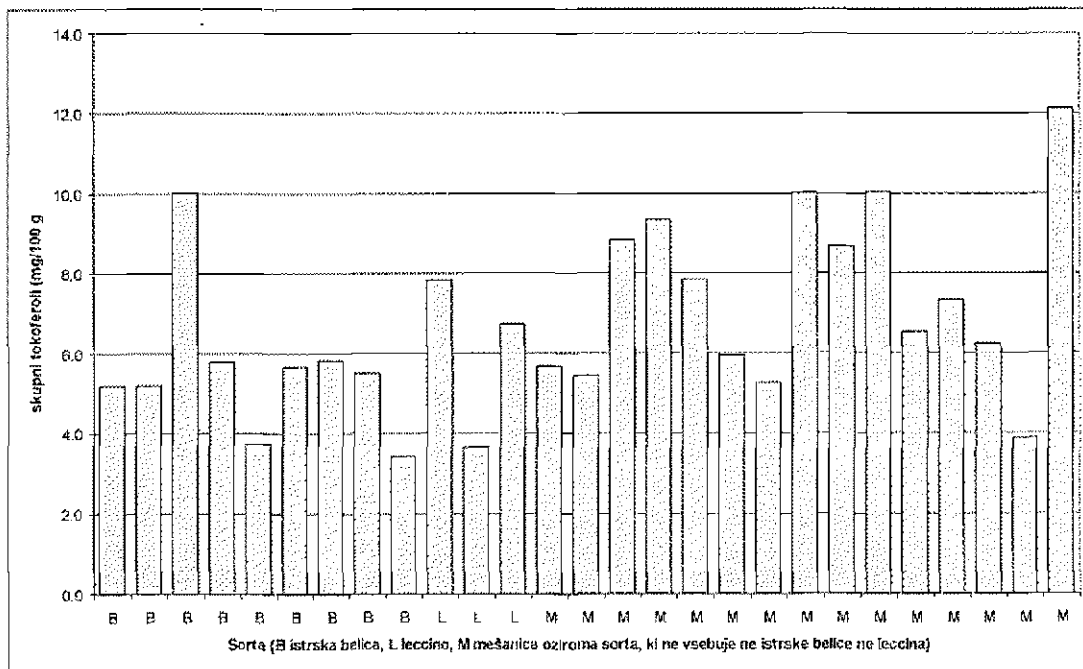
Tab. 2: Dobljeni rezultati za ST v vzorcih OO letnikov 1995, 1996 in 1997.  
 Tab. 2: Results of determination of ST in OO samples from the 1995, 1996 and 1997 crops.

| LETNIK | ŠTEVILO VZORCEV | POVPREČJE | STANDARDNI ODKLON | MEDIANA | MIN  | MAX   |
|--------|-----------------|-----------|-------------------|---------|------|-------|
| 1995   | 24              | 3,18      | 2,11              | 3,05    | 0,53 | 8,22  |
| 1996   | 27              | 6,73      | 2,26              | 5,95    | 3,43 | 12,13 |
| 1997   | 30              | 4,09      | 2,67              | 3,07    | 1,35 | 14,38 |

Sl. 11, 12 in 13 pa prikazujejo vsebnosti skupnih tokoferolov v vzorcih OO letnikov 1995, 1996 in 1997.

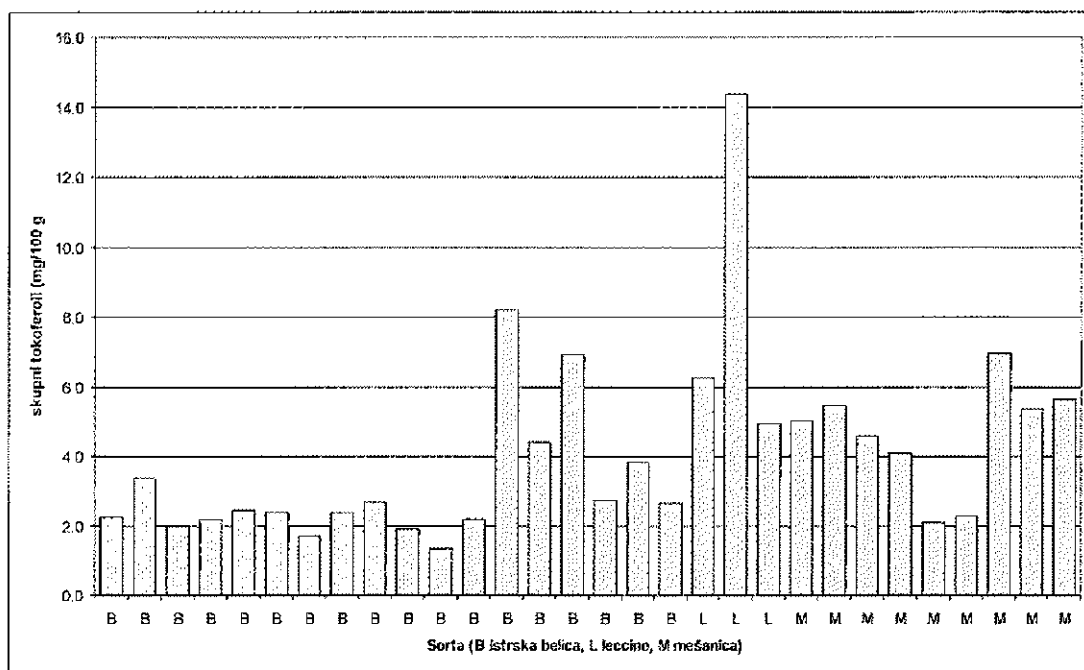


Sl. 11: Grafična ponazoritev vsebnosti skupnih tokoferolov za OO letnika 1995, določitev november 96.  
 Fig. 11: Graphical representation for the total tocopherols content in OO from the 1995 crop, analyzed in November 1996.



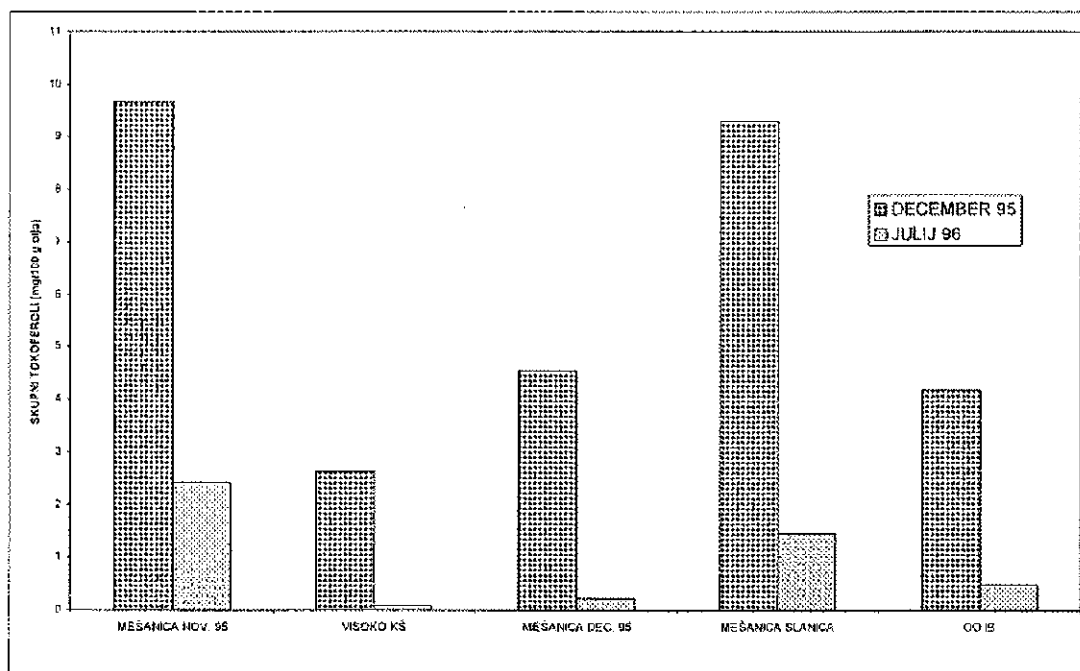
Sl. 12: Grafična ponazoritev vsebnosti skupnih tokoferolov za OO letnika 1996, določitev maj 97.  
 Fig. 12: Graphical representation for the total tocopherols content in OO from the 1996 crop, analyzed in May 97.





Sl. 13: Grafična ponazoritev vsebnosti skupnih tokoferolov za OO letnika 1997, določitev maj/junij 98.  
 Fig. 13: Graphical representation for the total tocopherols content in OO from the 1997 crop, analyzed in May/June 98.

in na sl. 14:



Sl. 14: Primerjalni graf vsebnosti skupnih tokoferolov v vzorcih oljčnih olj, analiziranih decembra 95 in julija 96 (po 6 mesecih namerno izbranega neustreznega skladiščenja).  
 Fig. 14: Comparative graph showing the content of the total tocopherols of OO samples, analyzed in December 95 and June 96 (after 6 months of deliberately chosen inadequate storage).

Tab. 3: Vsebnosti ST v vzorcih OO pred začetkom in po 6 mesecih neustreznega skladiščenja (rezultati so v mg skupnih tokoferolov na 100 g OO).

Tab. 3: The total tocopherols content in OO before and after 6 months of inadequate storage (results are in mg total tocopherols per 100 g of OO).

| VZOREC           | DOLOČITEV DEC. 95 | DOLOČITEV JUL. 96 |
|------------------|-------------------|-------------------|
| MEŠANICA NOV. 95 | 9.66              | 2.41              |
| VISOKO KŠ        | 2.64              | 0.09              |
| MEŠANICA DEC. 95 | 4.54              | 0.23              |
| MEŠANICA SLANICA | 9.30              | 1.44              |
| OO IB            | 4.20              | 0.50              |

### ZAKLJUČEK

Vsebnost skupnih tokoferolov v OO letnikov 1995, 1996 in 1997:

Primerjalni rezultati analiz vsebnosti skupnih tokoferolov v OO vseh treh letnikov kažejo na precejšnjo usklajenost vsebnosti tokoferolov. Povprečne vrednosti za letnike 1995, 1996 in 1997 so  $3,18 \pm 2,11$  mg/100 g OO;  $6,73 \pm 2,26$  mg/100 g OO in  $4,09 \pm 2,67$  mg/100 g OO. Standardni odkloni so za vse tri letnike izenačeni, kar kaže na precej dober izbor vzorcev OO za analizo, na primerljive klimatske in pridelovalne dejavnike znotraj posameznega letnika. V primerjavi s prejšnjimi letniki OO slovenske Istre so vsebnosti skupnih tokoferolov omenjenih letnikov 95, 96 in 97 znatno nižje, saj so bile te vrednosti pri letniku 1993 med 12 in 14 mg/100 g olja (Bučar-Miklavčič *et al.*, 1994). Ta podatek verjetno bolj kot na kemijske spremembe v času skladiščenja kaže na nizko vsebnost skupnih tokoferolov v plodovih samih oziroma v sveže predelanem olju (verjetno klimatski dejavniki med samo rastjo - količina padavin, temperatura).

Staranje izbranih OO letnika 1995 v neustreznih razmerah skladiščenja:

Omenili smo, da smo kontrolne vzorce šest mesecev skladiščili na svetlobi pri sobni temperaturi v prozorni embalaži. Takšno skladiščenje je bilo seveda namerno

izbrano, saj smo z njim hoteli ugotoviti, do katere največje mere se še zmanjša vsebnost tokoferolov. Ta vrednost je posredno merilo za rok trajanja olja. Ugotovili smo, da je v treh vzorcih od petih vsebnost skupnih tokoferolov padla pod 1 mg/100 g. Literatura navaja, da mora biti vsebnost skupnih tokoferolov, ki naj zagotovi minimalno antioksidativno stabilnost oljčnih olj, vsaj 6 mg/100 g olja (Cimato *et al.*, 1997). Seveda pa ta podatek ne upošteva morebitnih sinergizmov med vsebnostjo skupnih tokoferolov in skupnih polifenolov (Brighenti *et al.*, 1999). Iz vsebnosti skupnih tokoferolov v vzorcih po šestih mesecih neustreznega skladiščenja sledi, da neustrezno skladiščenje znatno zdesetka količino skupnih tokoferolov, kar posledično seveda pomeni, da taka olja niso več antioksidativno varna in se zato hitro pokvarijo. Še posebno nizka je bila vsebnost skupnih tokoferolov pri vzorcu z začetno visoko vsebnostjo prostih maščobnih kislin (>> 1%). Iz omenjenega sledi, da so vzorci, ki imajo že takoj ob predelavi visoko vsebnost prostih maščobnih kislin, še toliko manj stabilni.

### ZAHVALA

Laboratoriju LABS smo hvaležni za moralno in materialno asistenco pri eksperimentalnem delu, društvu DOSI pa za koordinacijo pri zbiranju vzorcev.

## TOCOPHEROLS IN OLIVE OILS FROM SLOVENE ISTRA IN THREE CONSECUTIVE YEARS

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## SUMMARY

*Antioxidants are compounds that protect olive oils (OO) against ageing. Vitamin E is an antioxidant that occurs, particularly in the form of  $\alpha$ -tocopherol, in extra virgin OO. The results of the analyses of the total tocopherol (ST) content in OO from Slovene Istra (crops 1995, 1996 and 1997) are the following: 3.18 mg/100 g; 6.73 mg/100 g in 4.09 mg/100 g. In the OO samples crop 1995, in which the impact of inadequate storage on the ST content was studied, their content fell below 1 mg/100 g.*

**Key words:** antioxidants, hydroxytyrosol, olive oil, polyphenols, tyrosol

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## POSTOPEK PRIDOBIVANJA CERTIFICIRANEGA SADILNEGA MATERIALA OLJKE (*Olea europaea* L.)

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### IZVLEČEK

Osnovni pogoj za uspešen razvoj oljkarstva je sajenje kakovostnega sadilnega materiala. V našem prispevku smo želeli opisati pot do certificiranih (brezvirusnih in na viruse testiranih) oljčnih sadik, ki bodo izpolnjevale vse kriterije zdaj v veljavi v državah Evropske unije. V primerjavi s standardnim sadilnim materialom, kakršnega pridelujemo trenutno, zagotavlja certificirana sadika višjo stopnjo selekcije, tako v zdravstvenem kot v genetskem pogledu.

**Ključne besede:** oljka, certificirani sadilni material

### UVOD

Oljčne sadike domače pridelave sodijo po EU normativih v kategorijo standardnega sadilnega materiala, kar pomeni, da pridobivamo razmnoževalni material (cepiče, potaknjence) iz matičnih dreves, ki so odbrana na podlagi rezultatov triletno pozitivne množične selekcije. Pridelava sadik v državah Evropske unije je danes že vezana predvsem na certificiran sadilni material. Tak način pridelave bo treba v prihodnjih letih vpeljati tudi v naše oljčne drevesnice. Z vpeljavo pridelave certificiranega sadilnega materiala smo najprej pričeli pri jablani kot najbolj razširjeni sadni vrsti v Sloveniji. Postopoma bomo ta način pridelave sadnih sadik vpeljevali se pri drugih sadnih vrstah, ki jih razmnožujemo pri nas. Podlaga takemu načinu pridelave je certifikacijska shema, ki za posamezno sadno vrsto predpisuje specifično zdravstveno kontrolo. Shema temelji na odbiri izvornih matičnih rastlin, ki jih odlikujejo najboljše zdravstvene in genetske lastnosti. Opredeljuje tudi njihovo nadaljnje razmnoževanje ter izvajanje postopkov vzdrževalne selekcije, ki poleg genetske kontrole vsebuje tudi metodiko preprečevanja reinfekcij matičnih rastlin. Med certificiran sadilni material

spadata glede na število testiranih virusnih bolezni kategoriji brezvirusni (VF- virus free) in na viruse testirani (VT-virus tested) sadilni material.

### CERTIFIKACIJSKA SHEMA SADILNEGA MATERIALA OLJKE

Pridelava podlag in certificiranih sadik oljke (*Olea sativa*, *Olea europaea* L.) temelji na certifikacijski shemi, ki jo priporoča EPPO (European and Mediterranean Plant Protection Organization) v svoji resoluciji št. 95/5236 (94/4339) in mora potekati skladno z določili "Zakona o semenu in sadikah" "Pravilnika o načinu odbiranja in potrjevanja matičnih rastlin in enotnih metodah za opravljanje strokovne kontrole nad pridelovanjem sadik" (Ur. l. SRS, št. 36/74) ter "Metode za odbiranje in potrjevanje matičnih sadnih rastlin in vegetativnih podlag". Postopek certifikacije je razdeljen na dve fazi:

- selekcijsko fazo, ki vključuje genetsko, zdravstveno in vzdrževalno selekcijo;
- fazo kontroliranega vegetativnega razmnoževanja matičnih dreves oziroma pridelavo certificiranih oljčnih sadik.

## CERTIFIKACIJSKA SHEMA SADILNEGA MATERIALA OLJKE

## ODBIRA IZHODIŠČNEGA MATERIALA

| ZLAHTNIH SORT  | PODLAG - SEJANCEV  | DREVES ZA PRIDELAVO KOŠČIC ZA VZGOJO SEJANCEV   |
|--|--|---|
| <ul style="list-style-type: none"> <li>- DREVO JE ODBRANO NA PODLAGI POZITIVNIH OCEN IZ OSNOVNE SELEKCIJE (pridelek, zmerna rast, zdravstveno stanje)</li> <li>- PODROBNO PREUČEVANJE KLONSKIH KANDIDATOV V NADALJNJIH 3 RODNIH LETIH</li> <li>- URADNO PRIZNAVANJE KLONA</li> </ul> | <ul style="list-style-type: none"> <li>- ODBIRA POTEKA ŽE V KALILNIH, POUDEK JE NA BUJNIH, DOBRO UKORENINJENIH IN ZDRAVIH SEJANCIH, KI MORAJO BITI BREZ VIDNIH ZNAKOV VIROZ IN BOLEZNI, KI SE PRENAŠAJO S CEPLJENJEM</li> <li>- VZGOJA NOVIH PODLAG</li> <li>- NADALJNJA PREUČEVANJA ODBRANIH SEJANCEV ZA MATIČNO DREVO, KI RABI ZA VEGETATIVNE PODLAGE</li> </ul> | <ul style="list-style-type: none"> <li>- ODBRANA DREVEŠA MORAJO BITI BREZ VIDNIH ZNAKOV VIROZ IN BOLEZNI, KI SE PRENAŠAJO S CEPLJENJEM</li> <li>- SEJANCI ODBRANIH DREVES MORAJO BITI MED SEBOJ ČIM BOLJ IZENAČENI IN ČIM BOLJ PODOBNI ODBRANEMU DREVESU</li> </ul> |

## KANDIDAT ZA IZVORNO MATIČNO RASTLINO

- IZOLACIJA V MREŽNIKU V SADILNEM LONCU S STERILIZIRANIM SUBSTRATOM
- TESTIRANJE NA VIRUSE (serološki testi, indeksiranje)
- ČE SO REZULTATI NEGATIVNI, POTEM NAMNOŽITEV KANDIDATA V BLOK IZVORNIH MATIČNIH RASTLIN

## IZVORNE MATIČNE RASTLINE

## RAZMNOŽITEV ZA BAZNI MATIČNI NASAD

- ZAGOTAVLJANJE RAZMER, KI ONEMOGOČAJO REINFEKCIJO
- IZOLACIJA V MREŽNIKU V SADILNEM LONCU S STERILIZIRANIM SUBSTRATOM
- NAJMANJ PO TRI RASTLINE POSAMEZNE SORTE ALI KLONA
- LETNO TESTIRANJE NA VIROZE (ArMV, CuMV, SLRV)
- LETNI VIZUALNI PREGLED NA BOLEZNI (*Verticillium dahliae*, *Pseudomonas syringae* subsp. *savastanoi*) IN ŠKODLJIVCE (*Euzophera pinguis*, *Parlatoria oleae*, *Saissetia oleae*)
- LETNI PREGLED NA POJAV MOREBITNIH SPREMEMB FENOTIPA

**Shema 1: Prikaz postopka selekcije in vzgoje izvornih matičnih rastlin za razmnožitev baznega matičnega nasada.**  
**Scheme 1: Presentation of the selection and breeding of original parental plants for the propagation of the basic parent plantation.**

V obeh fazah je pomembna natančna kontrola tehnoloških, pomoloških in botaničnih značilnosti (RIN - razpoznavnost, izenačenost, nespremenljivost) izvornih matičnih rastlin. Posebno pozornost moramo posvetiti morebitnemu pojavu mutantov (različkov, tipov) pri posamezni sorti. Postopke oziroma faze certifikacije prikazujeta shemi 1 in 2. Cilji, ki jih želimo doseči z uvedbo sodobne certifikacijske sheme za pridelavo sadilnega materiala oljke, so:

- zagotavljanje sadilnega materiala ustrezne genetske in zdravstvene vrednosti;
- zbiranje tipov in revitalizacija naše avtohtone sorte Istrska belica;
- skrb za ohranjanje genetskega bogastva oljke v Sloveniji.

## Osnovna (pozitivna množična) selekcija

## a) Žlahtnih sort

Pri genetski selekciji posameznih sort oljke je pomembno, da z osnovno odbito pričnemo pri dovolj velikem številu dreves na več različnih lokacijah. Odbrana drevesa morajo biti brez vidnih znakov bolezni ali prisotnosti škodljivcev oljke. Z opravljanjem osnovne selekcije začnemo v obdobju rodnosti dreves in traja 3 leta. Potekati mora skladno z "Metodo za odpiranje in potrjevanje matičnih sadnih rastlin in vegetativnih podlag". S potrjenih matičnih dreves lahko nato režemo potaknjence ali cepiče za pridelavo standardnih oljčnih sadik. Rezultate selekcije kasneje periodično preverjamo v rodni oljčnikih. Najboljša

drevesa pa kot klonske kandidate vključimo v postopek nadaljevalne selekcije.

#### b) Sejancev

Poudarek pri odbiri sejancev, ki se opravi že v samem kalilniku, je na dobri ukoreninjenosti, primerni bujnosti, dobrem splošnem zdravstvenem stanju in brez vidnih znakov viroz in drugih bolezní, ki se prenašajo s cepljenjem. Odbrani sejanec rabi kot matična rastlina za pridelavo vegetativnih podlag.

#### c) Matičnih dreves za pridelavo semena za sejance

Osnovno odbiro matičnih dreves, primernih za pridelavo semena za sejance, opravimo v večjem številu nasadov in pri dovolj velikem številu dreves. Odberemo le drevesa primerne bujnosti in rodnosti, brez znakov glivičnih bolezní ali prisotnosti škodljivcev oljke. Odbrana drevesa tudi ne smejo imeti vidnih znakov virusnih bolezní ali drugih bolezní, ki se prenašajo s cepljenjem, poleg tega morajo biti njihovi generativni potomci izenačeni v rasti in fenotipskih lastnostih sorte.

#### Nadaljevalna (klonska) selekcija ter vzgoja izvornih rastlin (nuclear stock)

Podlago za nadaljevalno (klonsko) selekcijo ter vzgojo izvornih rastlin oljke sestavljajo drevesa - klonski kandidati, ki so bila v 3-letnem postopku osnovne selekcije najbolj ocenjena. V postopek nadaljevalne selekcije vključimo le tiste klonske kandidate, ki se vsaj v eni izmed tehnološko pomembnih lastnosti pozitivno ločijo od drugih rastlin izbrane sorte. Pri vsakem odbranem drevesu - klonskem kandidatu, ki ga vključimo v nadaljevalno selekcijo, še posebej upoštevamo tipične biološke značilnosti sorte oziroma posebne lastnosti odbranega tipa, po katerih se ta tip loči od preostale populacije (tip rasti, oblika in barva lista, oblika in barva plodu, čas dozorevanja, občutljivost na pozebo, odpornost proti oljčni muhi...). Opazovanje istovetnosti sorte oziroma navedenih značilnosti je nujno zaradi ugotavljanja sorte RIN. Izpolnitev teh treh elementov je pogoj za potrditev nove sorte ali klona. Identifikacijo bioloških (botaničnih) značilnosti sorte ali klona opravimo z opisom po sistemu deskriptorjev, ki je sestavni del selekcijske metode, in jih priporoča UPOV (Union internationale pour la protection des obtentions végétales). Nadaljevalna (klonska) selekcija odbranih dreves traja 3 leta v polni rodnosti, v katerih moramo pri vsakem klonskem kandidatu opraviti meritve, analize in ocene naslednjih botaničnih, pomoloških, zdravstvenih ter tehnoloških značilnosti:

- meritve in analize plodov (opravimo v vsakem od treh let opazovanja);
- določitev izplena olja (opravimo v dveh od treh opazovalnih let);

- določitev kemijskih, organoleptičnih ter morebitnih drugih pomembnih značilnosti olja (opravimo v dveh od treh opazovalnih let);

- testiranja na virusne in druge bolezni oljke, ki se prenašajo s cepljenjem in jih predpisuje ta metodika (opravimo enkrat v treh letih).

Odbrana drevesa, ki jih vključimo v postopek nadaljevalne genetske selekcije, vegetativno razmnožimo s cepljenjem (cepimo na brezvirusno podlago) ali s potaknjenci. Razmnoževanje opravimo v primernem, pred insekti izoliranem rastlinjaku, ločeno od drugih rastlin. Za razmnoževanje uporabimo steriliziran substrat, rastline pa posadimo v lončke. V tej fazi vse razmnožene rastline ponovno testiramo na virusne in druge bolezni oljk, ki jih predpisuje ta metoda. Postopek nadaljevalne (klonske) selekcije nadaljujemo le z odbranimi zdravimi rastlinami. Rastline, pri katerih so bili rezultati testiranja negativni, prenesemo v ločen, posebej izoliran prostor rastlinjaka (mrežnika). Te rastline ponazarjajo izvorni matični blok klona (nuclear stock) za pridelavo baznega ali certificiranega razmnoževalnega materiala v primeru, da bo ta klon v postopku priznavanja tudi uradno potrjen. Tako razmnoženo količino rastlin razdelimo na 3 dele:

a) Določeno število rastlin klona (najmanj 3) ostane v izoliranem prostoru rastlinjaka (mrežnika), ki onemogoča reinfekcijo. Tako čuvane rastline so zdrav vir rastlinskega materiala za ponovno predrazmnožitev, v primeru reinfekcije ali uničenja izvornih matičnih rastlin v kolekciji - genski banki. Rastline v mrežniku morajo rasti v kontejnerjih s steriliziranim substratom.

b) Določeno število rastlin klona (najmanj 5), posadimo v poseben in od drugih oljčnikov ločen kolekcijski nasad, ki hkrati ponazarja gensko banko z referenčnimi drevesi sort oziroma klonov ter izvorni blok matičnih rastlin za vegetativno razmnoževanje baznih ali certificiranih oljčnih sadik. Tak nasad lahko posadimo na zemljišče, na katerem prej niso rastle lesnate rastline in na katerem je bila z analizo zemlje potrjena odsotnost nematod iz rodu *Xiphinema*. Drevesa v kolekcijskem nasadu vsako leto retestiramo na viruse oljke, ki se v naravi prenašajo z insekti. Prav tako moramo vsako leto opraviti vizualno kontrolo na bolezni: uvelost listja (*Verticillium dahliae*) in oljčni rak (*Pseudomonas syringae* subsp. *savastanoi*) ter na škodljivce: oljčno veščo (*Euzophera pinguis*), sivo jajčasto oljčno uš (*Parlatoria oleae*) ter oljčni medič ali ščitasta uš (*Saissetia oleae*). Rastline v kolekciji morajo biti letno vizualno pregledane na pojave morebitnih sprememb fenotipa.

c) Določeno število rastlin (najmanj 15) skupaj z določeno standardno sorto posadimo v poskusni rodni nasad za potrebe uradnega priznavanja klona.

Postopek uradnega priznavanja klona poteka skladno z veljavnimi zakonskimi in podzakonskimi predpisi in po navodilih "Podkomisije za sadne rastline" pri

"Strokovni komisiji za potrditev, dovolitev in varstvo sort kmetijskih in gozdnih rastlin" (Sortna komisija). Postopek traja 3 leta, začneši z letom vstopa v rodnost. Pri tem se še enkrat preverijo elementi RIN in vse lastnosti, ki jih opisuje klonska selekcija, oziroma stabilnost prenosa pozitivnih odbranih lastnosti klona iz izvirmih matičnih rastlin na vegetativno razmnožene potomce. Dokončen sklep o uradnem priznanju klona da "Sortna komisija" na podlagi zbranih podatkov o novem klonu v primerjavi z določenim standardom.

### Vzgoja baznih matičnih rastlin

Izvirne matične rastline so torej vzdrževane v izoliranih razmerah v mrežniku, lahko pa so tudi rastline v kolekciji - genski banki, ki so pod strogo vsakoletno kontrolo. Izvirne matične rastline zagotavljajo razmnoževalni material (cepiči, potaknjenci, sejanci) za pridobivanje baznih matičnih rastlin oz. baznega matičnega nasada. Bazni matični nasad mora biti posajen na primerno izolirani lokaciji (minimalno 20-metrski izolacijski pas, v katerem ne sme biti drugih oljk, in minimalno 2-metrski izolacijski pas brez kakršnega koli rastja). Zemljišče mora biti brez nematod iz rodu *Xiphinema* in gliv uvelosti listja (*Verticillium dahliae*). V

primeru namakanja mora biti voda prefiltrirana. Zaščita pred boleznimi in škodljivci mora biti intenzivna.

### Pridelovanje certificiranega sadilnega materiala

Bazni matični nasad zagotavlja razmnoževalni material za pridelovanje certificiranih sadik. Certificirane sadike kontroliramo vizualno najmanj 1x letno (zdravstvena in strokovna kontrola). Drevesnica, kjer pridelujejo certificiran sadilni material, mora biti na primerno izolirani lokaciji, kjer je bila z analizo zemlje potrjena odsotnost nematod iz rodu *Xiphinema*. V primeru, da nasad namakamo, je treba vodo pred namakanjem prefiltrirati. Okrog certificiranih sadik vzdržujemo 2 m širok varnostni pas brez vsakih rastlin, v nasadu pa tla čisto obdelujemo. Drevesnica mora biti vzorno vzdrževana in zaščiten pred boleznimi in škodljivci oljke. Postopke in zahteve glede pridelave certificiranih oljčnih sadik lahko kontrolira le specializirana pooblaščen ustanova, in sicer po kriterijih, ki jih priporoča EPPO. Certificiran sadilni material oljke lahko pridelujejo le za to posebej registrirani drevesničarji. Drevesničar ob registraciji podpiše tudi izjavo, s katero pristaja na vse faze kontrole pridelave certificiranih sadik s strani za to pooblaščen uradne ustanove.

### BAZNI MATIČNI NASAD

- RAZMNOŽEN JE IZ IZVIORNIH MATIČNIH RASTLIN
- ZAGOTOVITEV POTREBNEGA ŠTEVILA BAZNIH MATIČNIH RASTLIN
- ZEMLJIŠČE MORA BITI BREZ NEMATOD (*Xiphinema diversicaudatum*) IN GLIV (*Verticillium dahliae*)
- ZAGOTOVLJEN MINIMALNO 20-METRSKI IZOLACIJSKI PAS, V KATEREM NE SME BITI DRUGIH OLJK
- ZAGOTOVLJEN MINIMALNO 2-METRSKI IZOLACIJSKI PAS DO DRUGEGA RASTJA
- V PRIMERU NAMAKANJA MORA BITI VODA PREFILTRIRANA
- STALNA KONTROLA IN VARSTVO BAZNIH MATIČNIH RASTLIN PRED BOLEZNIMI IN ŠKODLJIVCI
- ZAGOTAVLJA RAZMNOŽEVALNI MATERIAL (CEPIČE, POTAKNJENCE) ZA PRIDOBIVANJE CERTIFICIRANIH SADIK

### PRIDELAVA CERTIFICIRANIH SADIK

- POTEKA V DREVESNICAH, KJER MORAJO BITI ZEMLJIŠČA BREZ NEMATOD (*Xiphinema diversicaudatum*) IN GLIV (*Verticillium dahliae*)
- VSAJ 4 METRE OKOLI ZEMLJIŠČA NE SME BITI DRUGIH OLJK
- VSAJ 2 METRA OKOLI ZEMLJIŠČA NE SME BITI DRUGEGA RASTJA
- V PRIMERU NAMAKANJA MORA BITI VODA PREFILTRIRANA
- RAZDELJEVANJE RAZMNOŽEVALNEGA MATERIALA DREVESNICAM MORA BITI POD KONTROLO POOBLAŠČENE ORGANIZACIJE, PRAV TAKO TUDI PRIDELAVA CERTIFICIRANIH SADIK
- VARSTVO SADIK V DREVESNICI MORA ZAGOTAVLJATI PRIDELAVO ZDRAVEGA SADILNEGA MATERIALA (brez bolezni in škodljivcev oljke)

### CERTIFIKACIJA

- KONTROLA KOLIČINE IN IZVORA BAZNEGA RAZMNOŽEVALNEGA MATERIALA
- IZDAJA ŠTEVILA ETIKET MORA USTREZATI ŠTEVILU PRIDELANIH CERTIFICIRANIH SADIK
- CERTIFIKAT JE DOKAZ PRIDELAVE SADIKE PO ZAHTEVANIH STOPNJAH SHEME CERTIFIKACIJE

Shema 2: Prikaz postopka pridelave certificirane sadike.

Scheme 2: Presentation of the acquisition of certified seedling procedure.



### Kontrola in status certificiranega sadilnega materiala

Vzgojo in uporabo razmnoževalnega materiala v drevesnicah, pridelovalkah certificiranih oljčnih sadik, kontrolira za to pooblaščen uradna inštitucija (zdravstveno stanje, poreklo, število certificiranih rastlin) na podlagi pregledov drevesnic ter dokumentov, ki se morajo o tem voditi in za kar je dolžan skrbeti drevesničar. Če se sadike ne vzgajajo v steriliziranem substratu v kontejnerjih (kontejnerska pridelava), je treba zemljišče drevesnice predhodno pregledati na nematode iz rodu *Xiphinema*. Prav tako se v drevesnici opravijo vsi potrebni fitopatološki pregledi (glivične in bakterijske bolezni) ter pregledi na škodljivce. Na podlagi vseh

opravljenih pregledov izda uradno pooblaščen ustanova, ki je te preglede opravila, predpisane certifikate (etikete). Število izdanih etiket mora ustrezati številu po tem postopku vzgojenih certificiranih sadik. Etikete nosijo serijsko številko, kar uradno pooblaščen ustanova, ki etikete izdaja, tudi kontrolira.

### Tehnična izvedba postopkov zdravstvene selekcije v sklopu nadaljevalne selekcije oljk

Virusi in druge bolezni ter škodljivci, katerih kontrolo zajema metoda po priporočilih EPPO, so prikazani v razpredelnici 1.

Tab. 1: Prikaz bolezni in škodljivcev na katere je potrebno testirati (pregledati) matične rastline oljk pri razmnoževanju certificiranih sadik kategorije na viruse testirani material (po EPPO).

Tab. 1: Presentation of diseases and pests to which parental olive plants must be tested in the propagation of certified seedlings of the category to viruses tested material (according to EPPO).

| ŠKODLJIV ORGANIZEM |   | GEOGRAFSKA RAZŠIRJENOST          | PRENOS V NARAVI                  |
|--------------------|---|----------------------------------|----------------------------------|
| VIRUSI             | ArMV (Arabis mosaic nepovirus)  | Evropa, Japonska, Nova Zelandija | <i>Xiphinema diversicaudatum</i> |
|                    | CuMV (Cucumber mosaic cucumovirus)  | po vsem svetu                    | <i>Aphis</i>                     |
|                    | SLRV (Strawberry latent ring spot nepovirus)                                  | Evropa                           | <i>Xiphinema diversicaudatum</i> |
| GLIVE              | <i>Verticillium dahliae</i>   | po vsem svetu                    |                                  |
| BAKTERIJE          | <i>Pseudomonas syringae</i> subsp. savastanoi                                 | po vsem svetu                    |                                  |
| INSEKTI            | <i>Euzophera pinguis</i><br><i>Parlatoria oleae</i><br><i>Saissetia oleae</i> |                                  |                                  |

Za certificirane sadike kategorije brezvirusni rastlinski material je potrebno, da so proste naslednjih virusnih bolezni:

- Arabis mosaic nepovirus (ArMV);
- Strawberry latent ring spot nepovirus (SLRV);
- Cherry leafroll nepovirus (CLRV);
- Olive latent ring spot nepovirus (OLRV);
- Cucumber mosaic cucumovirus (CuMV);
- Olive latent virus-1 (OLV-1);
- Olive latent virus-2 (OLV-2).

Do danes še ni znana nobena sorta ali tip oljke, ki bi ga lahko pri indeksiranju uporabili kot indikatorsko rastlino. Indeksiranje z mehanskim prenosom homogenizata na zeljaste indikatorje je mogoče pri vseh virusih oljke, ki so mehansko prenosljivi. Vse te viruse je mogoče relativno lahko prenesti na zeljaste indikatorje s homogenizati iz cvetnega prahu ali cvetov ter tudi iz listov in korenin.

Indikator *Chenopodium quinoa* uporabljamo za identifikacijo ArMV in SLRV, znaki okuženosti pa so

lokalne klorotične lezije in sistemski mozaik. Indikatorski rastlini *Nicotiana glutinosa* in *Nicotiana benthamiana* pa na infekcijo s SLRV reagirata z lokalnimi klorotičnimi lezijami. *Nicotiana benthamiana* je poleg tega, z znaki sistemnega mozaika indikator še za CuMV (Marte *et al.*, 1986).

Indikator *Cucurbita pepo* uporabljamo za identifikacijo CuMV, znak okuženosti je sistemski mozaik (Savino & Gallitelli, 1983).

Zaradi hitrejšega postopka testiranja in možnosti testiranja večjih serij vzorcev se za detekcijo virusov uporabljajo serološke metode (ELISA - Enzyme Linked Immunosorbent Assay). Testiranje z metodo DAS ELISA trenutno uporabljamo pri virusih SLRV in CuMV, ni pa ovir, da seroloških testov ne bi uporabili za testiranje vseh treh virusov (tudi ArMV), ki so trenutno predpisani (oziroma za vse viruse, kjer bodo na voljo protitelesa). Serološke teste na viruse sadnih rastlin in vinske trte opravljamo v laboratoriju Kmetijskega inštituta Slovenije.

## PROCEDURE FOR THE ACQUISITION OF CERTIFIED OLIVE (*Olea europaea* L.) PLANTING MATERIAL

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### SUMMARY

Basic condition for a successful development of olive growing is planting high-quality planting material. In this article we attempted to describe the way that has led to the certified (virus free and virus tested) olive seedlings, which would meet all the criteria now in force in the European Union. Compared with the standard planting material as grown at the moment, the certified seedling provides for a higher degree of selection in health as well as genetic aspects.

**Key words:** olive, certified planting material

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## VPLIV TRETIRANJA IN RAZLIČNIH OBDOBIJ PRIPRAVE POTAKNJENCEV NA UKORENINJANJE DVEH KULTIVARJEV OLJK (*OLEA EUROPAEA*)

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### IZVLEČEK

Kljub številnim raziskavam ukoreninjenja potaknjencev, podatkov o ukoreninjenju cv. 'Istrska belica' nimamo. Potaknjenci cv. 'Istrska belica' in cv. 'Leccino' so bili pripravljani v marcu, juliju in septembru v obdobju dveh let in tretirani s štirimi različnimi koncentracijami indol maslene kisline (IBA 2000 ppm, IBA 3000 ppm, IBA 4000 ppm, IBA 5000 ppm), z indol masleno kislino - IBA v koncentraciji 4000 ppm in dodatkom kaptana, pripravljenim rastnim regulatorjem Geromonom v tekoči obliki Geromon L) in v obliki prahu (Geromon P). Za kontrolo so služili netretirani potaknjenci. V poskusih je bilo ugotovljeno, da so v obeh letih marca, julija in septembra najboljše ukoreninili potaknjenci cv. 'Istrska belica' tretirani z IBA 4000 ppm in 5000 ppm. Poleg tega so bili enaki rezultati v marcu tudi z IBA 3000 ppm in IBA 4000 ppm z dodatkom kaptana, v juliju z IBA 4000 ppm z dodatkom kaptana, septembra pa tudi z IBA 3000 ppm in Geromonom P. V posameznih obdobjih so dobro ukoreninili tudi pri drugačnih tretiranjih. V obeh letih so bili pri cv. 'Leccino' julija in septembra najboljši rezultati pri tretiranju z IBA 2000 ppm, septembra tudi z IBA 3000 ppm in 4000 ppm. Prav tako so dobro ukoreninili potaknjenci cv. 'Leccino' tretirani z IBA 4000 ppm v vseh terminih v obeh letih razen septembra drugega leta in potaknjenci tretirani z Geromonom P marca prvo leto in septembra drugo leto.

**Ključne besede:** oljka, razmnoževanje, potaknjenci, tretiranje, fitoregulatorji, ukoreninjenje, kultivar

### UVOD

Ugotovljeno je, da je sposobnost ukoreninjenja potaknjencev oljke odvisna od različnih dejavnikov kot so pogoji siljenja, kultivarja, uporabe rastnih regulatorjev in drugih sredstev, termina jemanja potaknjencev, prehranjenosti in starosti matičnega drevesa.

Rezultatov in raziskav o ukoreninjenju različnih kultivarjev oljk je veliko, vendar podatkov o ukoreninjenju avtohtonega cv. 'Istrska belica' nimamo. Cv. 'Istrska belica' je v Slovenski Istri najbolj razširjen kultivar, vendar se po dosežanih podatkih slabše ukoreninja. Ugotoviti smo želeli primeren čas priprave potaknjencev cv. 'Istrska belica' pri uporabi različnih rastnih regulatorjev in različnih koncentracij indolmaslene kisline (IBA) v primerjavi s cv. 'Leccino'.

### PREGLED DOSEDANJIH OBJAV

Raziskave na področju ukoreninjenja potaknjencev oljk so šle v različne smeri, ki bi jih lahko razdelili v štiri skupine:

- spreminjanje vsebnosti različnih snovi v potaknjencih
- material za razmnoževanje
- razmere pri ukoreninjenju
- tretiranja potaknjencev.

Pri primerjavi ukoreninjenja potaknjencev jemanih iz osemdeset let starih matičnih dreves so ugotovili, da so potaknjenci iz enako starih dreves, ki so bila 1988 obnovljena, bolje ukoreninili. Pri zalitih (2 x) in pognojenih (spomfadi 2 kg/drevo) isto starih drevesih je bilo ukoreninjenje boljše, vendar še zmeraj manjše od potaknjencev z močno porezanih dreves (Chaari-Rkhiss & Trigui, 1996).

Walali in Loussert (1990a) sta ugotavljala ukoreninjenje apikalnih in bazalnih potaknjencev pri različnih terminih priprave in tretiranjem z različnimi koncentracijami IBA. Ugotovila sta, da so boljše (90%) ukoreninili bazalni potaknjenci od apikalnih (60,5%). Abousalim in Mansouri (1991) sta ugotavljala ukoreninjenje potaknjencev cv. 'Picholine marocaine' tretiranih z IBA v dveh različnih substratih (mivka, mivka in šota). Najbolje so ukoreninili potaknjenci iz srednjega dela poganjkov v mivki. Abousalim in sodelavci (1993) so pri istem kultivarju ugotavljali ukoreninjenje apikalnih, sredinskih in bazalnih potaknjencev v desetih fenoloških stadijih (od 205 do 107 dni pred začetkom cvetenja). Najboljše (73%) je bilo ukoreninjenje 178 dni pred cvetenjem, ko so plodovi dozorevali in se vijoličasto obarvali, najslabše pa 107 dni pred cvetenjem, ko so bili plodovi že črni. Največ korenin (7,1 kor./potaknjencev) je bilo 205 dni in (8,8 kor./potaknjencev) 178 dni pred cvetenjem. Povprečna dolžina korenin ni bila odvisna od termina priprave potaknjencev. Tip potaknjencev ni vplival na ukoreninjenje.

Veliko raziskav je vezanih na termin priprave potaknjencev in sortiment. Tako je Fouad s sodelavci (1990) opazoval ukoreninjenje potaknjencev osmih kultivarjev in ugotovil, da je najboljše ukoreninjenje v poletnem času zaradi manjše vsebnosti inhibitorjev - fenolov. Kultivar, ki je najboljše ukoreninil, je imel najnižjo vsebnost fenolov. Povezavo med terminom priprave potaknjencev in koncentracijo sta opazovala Gautam in Chauhan (1990). Pri divji oljki (*Olea cuspidata*) je bilo ukoreninjenje najboljše pri visokih koncentracijah IBA (5000 ppm in 7500 ppm) v juliju. Najboljši čas priprave potaknjencev v Severni Afriki je od marca do maja ter avgusta in septembra (Walali & Loussert, 1990b). Kultivarji imajo zelo različno moč ukoreninjenja, ustrezajo jim različni pogoji. Nekateri kultivarji imajo dobro moč ukoreninjenja, kakor cv. 'Carolea', ki je brez stimulacije dosegel kar 44% ukoreninjenja, medtem ko je cv. 'Coratina' samo 9,3%. Ob uporabi IBA je cv. 'Carolea' dosegla 81,3%, cv. 'Coratina' pa 44% ukoreninjenja (Pandey & Sinha, 1989). Tudi drugi avtorji so ugotavljali razliko med kultivarji, ki dobro ukoreninijo in takimi, ki slabo (Canozer & Ozachi, 1994; Ozkaya & Celik, 1994).

Potaknjence so raziskovalci tretirali z različnimi postopki in preparati, da bi dosegli čim boljše rezultate pri ukoreninjenju. IBA je najpogosteje uporabljen rastni regulator, čeprav še zmeraj preizkušajo tretiranje tudi z drugimi rastnimi regulatorji. Tako je Mancuso s sodelavci (1997) preizkušal ukoreninjenje oljk s kalijevo soljo indol maslene kisline (K - IBA) pa tudi indol očetno kislino (IAA), ki je dala nekoliko slabše rezultate od IBA. Brez rastnih regulatorjev večina kultivarjev slabo ukoreninja, uporaba različnih rastnih regulatorjev pa pozitivno vpliva na ukoreninjenje potaknjencev. Uporaba naftalen očetne kisline (NAA) 1000 in 2000 ppm je dala

enake rezultate v jesenskem in pomladanskem času, medtem ko je IBA dala podobne rezultate pri 1000, 2000 in 4000 ppm v pomladanskem času (Briccoli-Bati, 1988). Celik in sodelavci (1994) so ugotovili, da so v juniju pri tretiranju z IBA boljši rezultati ukoreninjenja cv. 'Gremlik' kot pri tretiranju z NAA. Wiesman in Lavee (1995) sta ugotovila, da tretiranje s saharozo in IBA izboljša ukoreninjenje v primerjavi s samo IBA.

Bazalna temperatura igra pomembno vlogo pri ukoreninjenju potaknjencev. Pri šestih bazalnih temperaturah se je najboljše (70%) izkazala začetna temperatura 30°C (15 dni), ki se zmanjša za naslednjih 5 dni na 25°C, kasneje pa ostane do konca na 18°C. Pri konstantni temperaturi 25°C, ki je običajna temperatura pri ukoreninjenju, je pod istimi pogoji ukoreninilo samo 34% potaknjencev (Mencuccini *et al.*, 1988). Kot zanimivo za izboljšanje ukoreninjenja se je izkazalo tridnevno hranjenje potaknjencev pri 4°C pred vlaganjem v substrat (Briccoli - Bati & Lombardo, 1988).

## MATERIALI IN METODE

Cv. 'Istrska belica' je avtohton in najbolj razširjen kultivar v Slovenski Istri. Večina starih nasadov je bila po pozebi 1956 precepiljena s cv. 'Istrska belica'. V mladih nasadih sta najbolj zastopana kultivarja cv. 'Istrska belica' in cv. 'Leccino'. Potaknjence smo jemali z matičnih dreves obeh kultivarjev dve leti ob koncu marca, v sredini julija in drugi polovici septembra. Matična drevesa so v oskrbi posameznikov in sicer sta kultivarja v različnih nasadih z različno oskrbo. Iz enoletnih poganjkov smo pripravili potaknjence približno 15 cm dolžine, na katerih smo na zgornjem delu pustili 4 liste. V poskus smo vključili 8 obravnavanj z različnimi tretiranjmi:

- IBA (indol maslena kislina) 2000 ppm,
- IBA 3000 ppm,
- IBA 4000 ppm,
- IBA 5000 ppm,
- IBA 4000 ppm in kaptan,
- komercialni pripravek Geromon v tekoči obliki z rastnim regulatorjem NAA (naftalen očetna kislina) - Geromon L v 5% koncentraciji,
- komercialni pripravek Geromon v prahu z rastnim regulatorjem NAA (naftalen očetna kislina) - Geromon P in
- vodno-alkoholna raztopina - kontrola.

Ukoreninjenje je potekalo v pokritih ogrevanih mizah v rastlinjakih po vzoru Fontanazza iz 1978 leta. Kot substrat smo uporabili perlit, ki je bil bazalno ogrevan na 24° do 26°C. Pred vlaganjem potaknjencev smo substrat namočili do izpiranja, kasneje pa smo to opravili enkrat tedensko. Potaknjence smo vlagali v razdaljah 2 x 3 cm. Poskus je bil zastavljen z osmimi obravnavanji dveh kultivarjev v petih blokkih po 20 potaknjencev. Po dveh mesecih smo opazovali število

ukoreninjenih potaknjencev in statistično ovrednotili z analizo variance. Razlike med posameznimi obravnavanji smo testirali s Studentovim t - testom pri stopnji tveganja 0,05 in 0,01.

**REZULTATI**

Na podlagi poskusov smo ugotovili, da različna tretiranja in čas priprave potaknjencev vplivata na število ukoreninjenih potaknjencev. Kultivarja cv. 'Istrska belica' in cv. 'Leccino' ne reagirata enako na tretiranje in čas priprave potaknjencev. Ukoreninjenje cv. 'Istrska belica' se je bolje obneslo v obeh letih julija, pa tudi marca drugo leto in septembra prvo leto v primerjavi s cv. 'Leccino'. Oba kultivarja sta pokazala dobre rezultate pri tretiranju z IBA 4000 z dodatkom kaptana v vseh terminih, razen drugo leto septembra. Pri cv. 'Istrska belica' smo pri ukoreninjenju dosegli bistveno višje rezultate (najvišji 84% pri tretiranju z IBA 4000 v juliju drugo leto), medtem ko pri cv. 'Leccino' nižje (najvišji 69% pri tretiranju z IBA 4000 v juliju prvo leto). Glede na podatke o ukoreninjenju cv. 'Leccino' ugotavljamo v naših poskusih zelo nizek % ukoreninjenja.

**Tab. 1: Odstotek ukoreninjenih potaknjencev cv. 'Istrska belica' v treh terminih dveh let (1991 in 1992).**  
**Tab. 1: Percentage of rooted cuttings of cv. 'Istrska belica' in three periods of two years (1991 and 1992).**

|                   | III/91 | III/92 | VII/91 | VII/92 | IX/91 | IX/92 |
|-------------------|--------|--------|--------|--------|-------|-------|
| IBA 2000          | 6      | 86     | 70     | 64     | 34    | 7     |
| IBA 3000          | 16     | 70     | 73     | 65     | 62    | 18    |
| IBA 4000          | 13     | 60     | 53     | 78     | 64    | 13    |
| IBA 5000          | 10     | 76     | 62     | 75     | 62    | 13    |
| Kontrola          | 11     | 14     | 13     | 0      | 19    | 0     |
| Geromon L         | 0      | 66     | 0      | 65     | 14    | 6     |
| Geromon P         | 13     | 34     | 49*    | 81     | 77    | 24    |
| IBA 4000 + kaptan | 14     | 70     | 67     | 84     | 63    | 6     |
| Povprečno         | 10,6   | 58,0   | 48,4   | 64,0   | 49,4  | 10,9  |

Opombe: \* = tveganje 0,05  
 zasenčeno = tveganje 0,01  
 poudarjeno = pozitivno odstopanje v obeh letih pri tveganju 0,01

V marcu so v obeh letih boljše (statistično značilno pri tveganju 0,01) ukoreninjali potaknjenci cv. 'Istrska belica' tretirani z IBA 3000, IBA 4000, IBA 5000 in IBA 4000 z dodatkom kaptana. V prvem letu so se statistično značilno razlikovala pri tveganju 0,01 tudi tretiranja z Geromonom P in kontrola, v drugem letu pa tretiranje z Geromonom L pri istem tveganju. V prvem letu je bilo ukoreninjenje v celoti slabo (v povprečju 10,6%) in dokaj izenačeno, saj je odstopalo samo tretiranje z IBA 2000 in Geromonom L. V naslednjem letu je bilo

ukoreninjenje bistveno višje (v povprečju 58%) in se je bistveno razlikovalo od kontrole.

V juliju je pri tveganju 0,01 v obeh letih statistično značilno odstopalo v pozitivnem smislu tretiranje z IBA 4000, IBA 5000 in IBA 4000 z dodatkom kaptana. Tretiranje z Geromonom P je bilo statistično značilno boljše v obeh letih, vendar v prvem letu le z 0,05 tveganjem. V prvem letu je pozitivno odstopalo tudi tretiranje z IBA 2000 in IBA 3000, medtem ko v drugem letu ni. V obeh letih je bilo ukoreninjenje v povprečju dobro, v prvem letu je ukoreninilo povprečno 48,4% potaknjencev, medtem ko v drugem letu celo 64,0%. Pri tretiranju z IBA 2000, IBA 3000 in Geromonu L je ukoreninilo drugo leto 64-65%, vendar ni bilo v skupini najboljših ukoreninjenih potaknjencev, saj so tretiranja z IBA 4000, IBA 5000, IBA 4000 s kaptanom in Geromon P dosegla od 75 do 84% ukoreninjenje.

V obeh letih je septembra statistično značilno pozitivno odstopalo (pri tveganju 0,01) tretiranje z IBA 3000, IBA 4000, IBA 5000 in Geromon P. Prvo leto je pri istem tveganju statistično odstopalo tudi tretiranje z IBA 4000 z dodatkom kaptana, ko je bilo povprečno ukoreninjenje vseh obravnavanj 49,4%. V naslednjem letu je bil rezultat bistveno slabši - 10,9%.

**Tab. 2: Odstotek ukoreninjenih potaknjencev cv. 'Leccino' v treh terminih dveh let (1991 in 1992).**  
**Tab. 2: Percentage of rooted cuttings of cv. 'Leccino' in three periods of two years (1991 and 1992).**

|                   | III/91 | III/92 | VII/91 | VII/92 | IX/91 | IX/92 |
|-------------------|--------|--------|--------|--------|-------|-------|
| IBA 2000          | 19     | 18     | 68     | 54     | 27    | 28    |
| IBA 3000          | 25*    | 26     | 34     | 26     | 32    | 41    |
| IBA 4000          | 23*    | 33     | 24     | 23     | 34    | 36    |
| IBA 5000          | 19     | 13     | 28     | 26     | 18*   | 34    |
| Kontrola          | 4      | 4      | 16     | 0      | 2     | 27    |
| Geromon L         | 0      | 13     | 0      | 5      | 3     | 18    |
| Geromon P         | 28     | 11     | 39     | 35     | 12    | 30    |
| IBA 4000 + kaptan | 41     | 63     | 69     | 66     | 32    | 16    |
| Povprečno         | 19,9   | 22,6   | 34,7   | 29,4   | 20,0  | 28,7  |

Opombe: \* = tveganje 0,05  
 zasenčeno = tveganje 0,01  
 poudarjeno = pozitivno odstopanje v obeh letih pri tveganju 0,01

V marcu se v obeh letih pri tveganju 0,01 statistično najboljše obneslo tretiranje potaknjencev cv. 'Leccino' z IBA 4000 z dodatkom kaptana. Prvo leto je pri tveganju 0,01 enako odstopalo tudi tretiranje z Geromonom P, pri tveganju 0,05 pa je odstopalo tudi tretiranje z IBA 3000 in IBA 4000. Ukoreninjenje je bilo v obeh letih dokaj nizko, prvo leto je bilo povprečje vseh obravnavanj 19,9%, drugo leto pa 22,6%.

V obeh letih je v juliju statistično značilno pozitivno

odstopalo tretiranje z IBA 2000 IBA 4000 z dodatkom kaptana. Iz tega bi lahko sklepali, da bi mogoče tretiranje z IBA 2000 z dodatkom kaptana dalo še boljše rezultate. Povprečno ukoreninjenje vseh obravnavanj pripravljenih julija prvo leto je bilo najvišje od vseh terminov in sicer 34,7%, medtem ko drugo leto nekoliko nižje 29,4%.

V septembru so v obeh letih statistično značilno (pri tveganju 0,01) pozitivno odstopala tretiranja z IBA 2000, IBA 3000 in IBA 4000. V prvem letu je odstopalo tudi tretiranje z IBA 4000 z dodatkom kaptana (pri tveganju 0,01), medtem ko v naslednjem letu ni, kljub temu, da je bilo tretiranje z IBA 4000 uspešno. Tretiranje z IBA 5000 je bilo statistično značilno boljše v obeh letih, vendar v prvem letu z 0,05% tveganjem. V drugem letu je bilo statistično značilno boljše tudi tretiranje z Geromonom P. Povprečno ukoreninjenje vseh obravnavanj pripravljenih v septembru je bilo v prvem letu 20%, v drugem letu pa 28,7%.

### RAZPRAVA

Poskus, ki je bil zastavljen v dveh letih, nam je sicer odgovoril na nekatera vprašanja, vendar nam je ostalo še veliko nepojasnjenih vprašanj. Tako kot so nekateri že ugotovili, je spontano ukoreninjenje potaknjencev različnih kultivarjev zelo različno, prav tako pa posamezen kultivar zahteva drugačno tretiranje.

Na podlagi dosedanjih rezultatov ugotavljamo pri cv. 'Istrska belica' kar dobro naravno sposobnost ukoreninjenja. Ukoreninjenje brez rastnih regulatorjev je bilo v prvem letu uspešno v vseh terminih, medtem ko julija in septembra drugo leto cv. 'Istrska belica' ni koreninila. Z gotovostjo lahko trdimo, da je za boljši % ukoreninjenja potrebno dodajanje rastnih regulatorjev tako pri cv. 'Istrska belica' kot pri cv. 'Leccino'.

Ugotovili smo, da lahko v vseh terminih dosežemo dober % ukoreninjenja cv. 'Istrska belica'. Večja so nihanja od leta do leta, kakor pa med termini samimi. Pojavlja se torej vprašanje, kako doseči dobro ponovljivost rezultatov v različnih letih. Ravno zaradi tega bi bilo primerno poskus izvajati več let, da bi lahko ugotovili najprimernejši termin za pripravo potaknjencev. Seveda bi lahko neponovljivost rezultatov povezali tudi z različno prehranjenostjo rastlin, ki je lahko povezana z naloženostjo matičnih dreves, z izmenično rodnostjo, gnojenjem. Za razjasnitev tega problema bi bilo najbrž smiselno jemati potaknjence iz enotnega nasada z nadzorovanim gnojenjem, rodnostjo, časom obiranja in vsebnostjo hranil ter ogljikovih hidratov v potaknjencih. Rezultati ukoreninjenja potaknjencev cv. 'Leccino' so prenizki, na podlagi teh rezultatov bi lahko trdili, da se cv. 'Istrska belica' bolje ukoreninja od cv. 'Leccino', čeprav večina pridelovalcev trdi nasprotno. Te podatke si je težko pojasniti, vendar bi si to lažje pojasnili z razlikami zaradi

različnih tipov cv. 'Leccino'. Seveda pa je to lahko povezano tudi s prehranjenostjo rastlin in zgoraj navedenimi možnostmi. Podatkov o poskusih ukoreninjenja cv. 'Istrska belica' ni.

V vseh terminih bi na podlagi dosedanjih rezultatov lahko svetovali tretiranje potaknjencev cv. 'Istrska belica' z IBA 4000 ali 5000 ppm. Dobro se je pokazalo tudi tretiranje z IBA 4000 ppm in dodatkom kaptana in sicer vsaj enako dobro kot tretiranje samo z IBA 4000 ppm, razen v septembru zadnje leto. Ker je bil dosežen enak rezultat tudi pri cv. 'Leccino', si lahko razlagamo, da je prišlo do nepojasnjene napake, ki bi jo mogoče lahko pripisali kaptanu. Pri cv. 'Leccino' smo ugotovili, da mu ustrezajo nižje koncentracije IBA. V vseh terminih so bili doseženi najboljši rezultati s tretiranjem z IBA 4000 ppm in dodatkom kaptana (razen septembra drugo leto). Tretiranje samo z IBA 2000 ppm je bilo uspešno julija in septembra v obeh letih. Na podlagi tega bi lahko svetovali marca tretiranje z IBA 3000 in 4000 ppm, julija z IBA 2000 ppm, v septembru pa lahko z vsemi tremi koncentracijami (IBA 2000, 3000, 4000 ppm), lahko pa tudi z IBA 5000. Na podlagi dosedanjih rezultatov bi lahko sklepali, da bi pri koncentraciji 2000 ppm in dodatku kaptana v poletnem času lahko dosegli še boljše rezultate.

Kot zanimiv pripravek se je pri razmnoževanju cv. 'Istrska belica' pokazal tudi Geromon P, s katerim smo dosegli dobre rezultate takorekoč v vseh poskusih, razen drugo leto marca. Podatek je zanimiv predvsem za posameznike, ki bi želeli sami poskušati razmnoževati, saj je vsem dostopen in ga uporabljamo brez redčenja. Zanimivo je, da se ta pripravek ni enako dobro izkazal pri razmnoževanju cv. 'Leccino', pri katerem se je obnesel samo v dveh terminih - marca prvo leto in septembra drugo leto. Pripravek Geromon L, ki je ravno tako dosegljiv vsem, pri ukoreninjenju cv. 'Leccino' ni dal dobrih rezultatov, pri cv. 'Istrska belica' pa so bili rezultati različni.

### ZAKLJUČEK

V dveh letih smo opazovali ukoreninjenje potaknjencev cv. 'Istrska belica' v primerjavi z ukoreninjenjem cv. 'Leccino'. V treh terminih smo ugotavljali ukoreninjenje potaknjencev obeh kultivarjev pri osmih različnih obravnavanjih.

V poskusu smo ugotovili boljše ukoreninjenje cv. 'Istrska belica' od cv. 'Leccino', čeprav večina pridelovalcev trdi nasprotno. V vseh terminih lahko na podlagi poskusa priporočamo tretiranje potaknjencev cv. 'Istrska belica' z IBA in sicer z višjimi koncentracijami, predvsem 4000 ppm in 5000 ppm, lahko pa tudi z 3000 ppm. Pri vseh naštetih koncentracijah IBA priporočamo dodatek kaptana, ki nekoliko zviša % ukoreninjenja potaknjencev. Dobre rezultate je pri cv. 'Istrska belica' pokazal pripravek Geromon P, ki ga lahko priporočamo

za manjše pridelovalce sadik (za lastno potrebo) zaradi enostavnosti nabave in uporabe. Splošno bi lahko na podlagi tega poskusa rekli, da cv. 'Leccino' ustrezajo nekoliko nižje koncentracije IBA, predvsem v poletnem času (2000 ppm). Spomladi priporočamo za cv. 'Leccino' IBA 3000 ppm in 4000 ppm, septembra pa lahko približno enako uspešno uporabimo vse koncentracije IBA. Dodatek kaptana zvišuje ukoreninjenje potaknjencev cv. 'Leccino', kar pomeni, da bi lahko pri nižji koncentraciji IBA v poletnem času in z dodatkom kaptana dosegli še boljše rezultate.

Na podlagi dobljenih rezultatov dveh let smo

ugotovili, da so nihanja med posameznimi leti velika. Dveletni poskusi nam ne omogočajo natančno priporočanje termina in načina tretiranja kultivarjev. Z večjo gotovostjo bi lahko to priporočali, če bi poskus izvajali več let (vsaj pet). Hkrati pa bi lahko z izključevanjem nekaterih vplivov omogočili boljše ponovljivost rezultatov. Potaknjence obeh kultivarjev bi bilo najbolje jemati v enem nasadu z obema kultivarjema. V nasadu naj bi nadzorovali gnojenje, rodnost, izmeničnost rodnosti, čas obiranja ... in ugotavljali vsebnost hranil in ogljikovih hidratov v času priprave potaknjencev.

## INFLUENCE OF TREATMENT AND DIFFERENT PREPARATION PERIOD OF CUTTINGS ON ROOTING OF TWO OLIVE VARIETIES (*OLEA EUROPAEA*)

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### ABSTRACT

Despite many researches on rooting of olive cuttings, we do not have any information on rooting of cv. 'Istrska belica'. Cuttings of cv. 'Istrska belica' and cv. 'Leccino' were prepared in March, July and September in the period of two years and treated with four different concentrations of indole butyric acid (IBA 2000 ppm, IBA 3000 ppm, IBA 4000 ppm, IBA 5000 ppm), indole butyric acid - IBA 4000 ppm concentration with added captan, liquid (Geromon L) and powdered (Geromon P) prepared fitoregulators. Non treated cuttings were used for control. The results of the show that in March, July and September of both years there was the best rooting of cuttings of cv. 'Istrska belica' treated with IBA 4000 ppm and IBA 5000 ppm. Same results were achieved in March with IBA 3000 ppm and IBA 4000 ppm concentration with added captan, in July with IBA 4000 ppm concentration with added captan, in September with IBA 3000 ppm and Geromon P. At some point during the experiment good rooting was achieved with a different treatment. In July and September of both years best results of rooting were achieved for cv. 'Leccino' with treatment with IBA 2000 ppm, in September also with IBA 3000 ppm and IBA 4000 ppm. There was also a good rooting of cuttings of cv. 'Leccino' treated with IBA 4000 ppm in all periods of both years except in September of the second year, and cuttings treated with Geromon P in March of the first year and in September of the second year.

**Key words:** olive, propagation, cuttings, treatment, fitoregulators, rooting, cultivar

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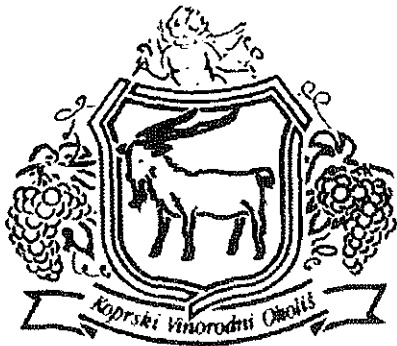
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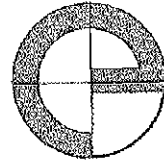


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