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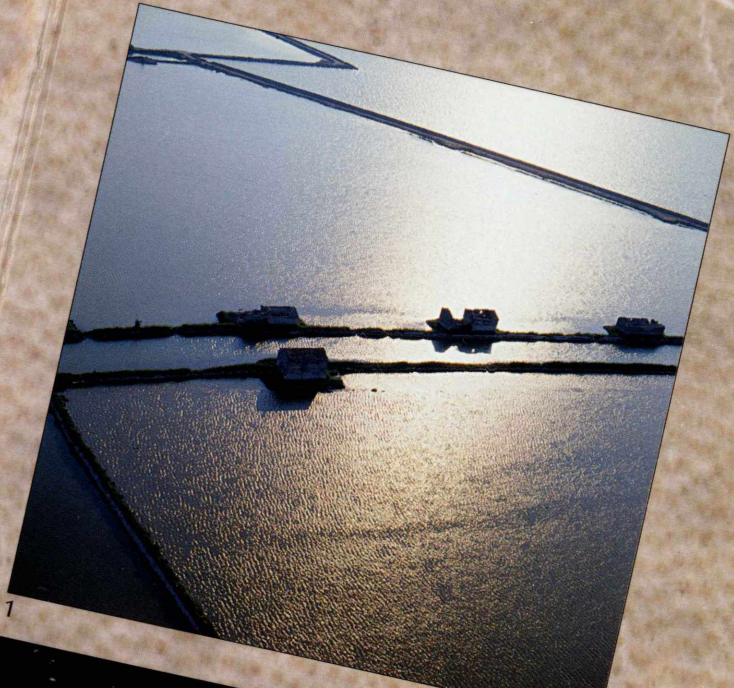
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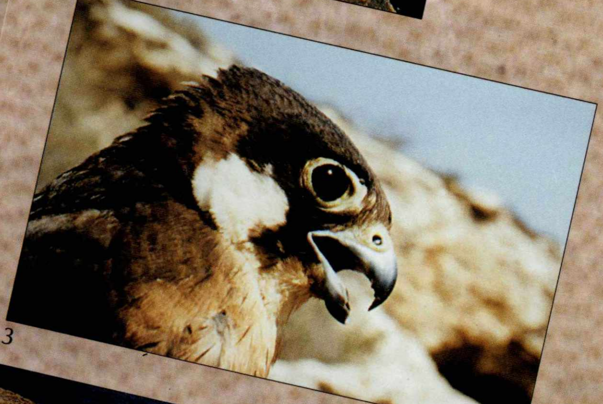
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PRESENCE OF THE GREAT WHITE SHARK, *CARCHARODON CARCHARIAS* (LINNAEUS, 1758) IN THE CATALONIAN SEA (NW MEDITERRANEAN): REVIEW AND DISCUSSION OF RECORDS, AND NOTES ABOUT ITS ECOLOGY

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ABSTRACT

Occurrences of the great white shark Carcharodon carcharias *in the Catalonian Sea have been poorly reported and at times poorly examined as well. Therefore, historical and contemporary records have been revised and analysed to check on their validity. Furthermore, some brief biological data are presented.*

Key words: great white shark, *Carcharodon carcharias,* Catalonian Sea, records, ecology

PRESENZA DELLO SQUALO BIANCO, *CARCHARODON CARCHARIAS* (LINNAEUS, 1758) NEL MARE DELLA CATALOGNA (MEDITERRANEO NORD-OCCIDENTALE): REVISIONE E DISCUSSIONE DELLE SEGNALAZIONI CON NOTE DI ECOLOGIA

SINTESI

La presenza dello squalo bianco Carcharodon carcharias *nel Mare della Catalogna è stata scarsamente riportata e talora non esaminata in dettaglio. Pertanto le segnalazioni storiche ed attuali sono state riviste ed analizzate al fine di valutarne la validità. Vengono inoltre presentati alcuni brevi dati sulla biologia della specie.*

Parole chiave: Squalo bianco, *Carcharodon carcharias,* Mare della Catalogna, segnalazioni, ecologia

INTRODUCTION

The great white shark *Carcharodon carcharias* (Linnaeus, 1758) is a cosmopolitan species inhabiting coastal and temperate waters (Compagno, 1984). In the Mediterranean, it has been mentioned in works of general ichthyology (Cadenat & Blache, 1981; Quéro, 1984; Moreno, 1995; Barrull & Mate, 1996; Notarbartolo di Sciara & Bianchi, 1998), and it also appears broadly registered in local faunistic compiled works, for instance in the waters of Greece (Papakostantinou, 1988), Italy (Tortonese, 1956), France (Moreau, 1881), and Algeria (Duméril, 1865), and also in the Adriatic (Šoljan, 1984) and Alboran Seas (Lozano Rey, 1921). Recently, Mojetta *et al.* (1997) and De Maddalena (1999) prepared a thorough summary of records in Italian waters, and likewise De Maddalena (2000) in the waters of the Northern and Central Adriatic. Recently, Fergusson (1996) made a revision of the white shark's occurrences in the entire Mediterranean. The main objective of the present work is to get acquainted with the presence of the white shark in the Catalonian Sea, as well as to revise and discuss the records of this species.

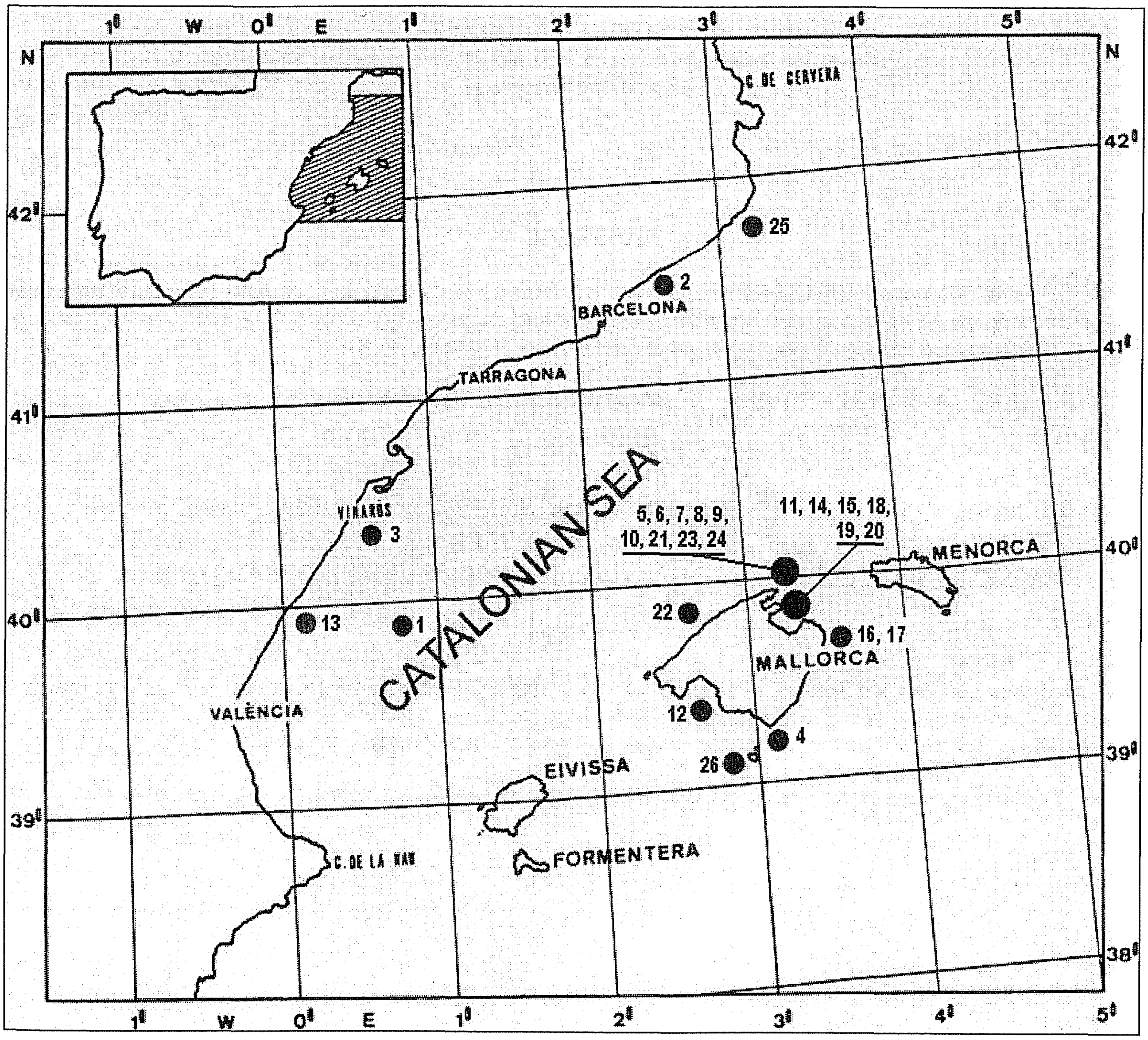

*Fig. 1 : **Localities of the specimens of great white shark*** *Carcharodon carcharias* ***in the Catalonian Sea (NW Mediterranean).***

Sl. 1: Lokacije osebkov belega morskega volka *Carcharodon carcharias* ***v Katalonskem morju (SZ Sredozemlje.***

MATERIALS AND METHODS

The area encompassed by the revision comprises the part of the western Mediterranean Sea known as the Catalonian Sea, whose limits were mapped by Danish Oceanographical Expeditions, 1908-1910 (Schmidt, 1912). The Catalonian Sea is a subunit of the Balearic Sea, limited by an imaginary line running from La Nau Cape (38°45'N) to Cervera Cape (42°30'N), including the Balearic Islands (Fig. 1).

This region coincides more or less with the authors' usual work area, thus enabling them to draw on a certain familiarity and background that proved invaluable in preparing the present compilation.

Data were collected from five main sources: a) books and scientific journals, b) circumstantial articles including photographs of captured specimens, c) sightings reports, d) location and study of material preserved in private collections or natural history museums, and e) collaboration with other researchers and private citizens. For the compilation of bibliographical references and scientific citations within the waters of the study area, it was sufficient to bring up to date the work of Lloris *et al.* (1984). In every case, whenever possible, the following data were collected: date and locality of the record; total length (TL) in cm, weight (W) in kg, and sex of the animal; type of record (capture, sighting or stranding). Total length and weight were estimations reported by fishermen.

RESULTS

The collected information include 26 specimens sighted or captured in the Catalonian Sea between 1878 and 2000 (Tab. 1). A total of 21 cases refer to Balearic Islands, 3 to Castelló, 1 to Girona and 1 to Barcelona.

Pérez Arcas (1878) mentions the capture of a specimen in 1878 along the coast of Valencia, between the Columbretes islands and Castelló. Surely this was the first documented record in the Catalonian Sea waters, often taken as reference in later works, such as those by Sánchez-Comendador (1904), Ferrer Aledo (1906), Fage (1907), Gibert (1911), De Buen (1935) and Lozano Cabo (1963). The contributions of these authors are not documented neither with date nor capture place, neither with sighting nor beaching of the white shark. Thus we can consider them simple general listings. Lozano Rey (1928) refers to a specimen caught in 1878 *"... en las islas Columbretes no lejos de Castellón de la Plana..."* ("...off the Columbretes Islands not far from Castellón de la Plana..."). The description of the capture leads us to believe that it could be the same individual as examined by Pérez Arcas due to the same date of capture, fishing place, weight of the animal, the only (small) difference being the total length, surely as a result of unreliable measure units being used. The same author further states in his work records from Mallorca (Balearic Islands), Vinaròs (Castellò), and *"...en distintas partes de nuestro litoral mediterráneo..."* ("...in different places along our Mediterranean coast..."), without any documented specification. Fergusson (1996) reported on three captures from the Columbretes Islands, Castellón and Valencia (Fergusson's cases n° 83, 84 and 85) but they are surely the same catch as reported by Pérez Arcas (1878).

Barrull & Mate (1993-1994, 1996) refer to a specimen captured in the *almadraba* (enclosed tuna net) off Vilassar de Mar (Barcelona). Two dental pieces of this individual, catalogued with the registration numbers MZB-82-5316 and MZB-82-5317, were deposited in the Museum of Zoology of Barcelona on December 16th 1912 (Fig. 2). These teeth are documental evidence of the first white shark record in Catalonia, and the second chronologically dated in the Catalonian Sea. Corbera *et al.* (1996) comment on the capture of a specimen off Premià de Mar (Barcelona), but this record is not valid due to an error (Corbera, *pers. comm.),* and it refers to the animal studied by Barrull & Mate (1993-1994).

Samper (1979) points out the capture of a 500 cm long and 1,500 kg heavy female along the coast of Castelló *"...hace ya algunos años..."* ("...some years ago..."). Asensi (1980) refers to an individual caught in 1962 off Castelló as well. This might be the same individual, but as Asensi has never responded to our requirement to confirm this record, we consider it doubtful.

Ramis & Terrasa (1988) comment on sighting and capture of 18 individuals with enclosed tuna nets *(almadrabas)* off Balearic Islands between 1941 and 1976. Most of these records are documented with pictures of the animals and explanations of the fishermen that made the captures (Figs. 3, 4). Further 12 individuals were said

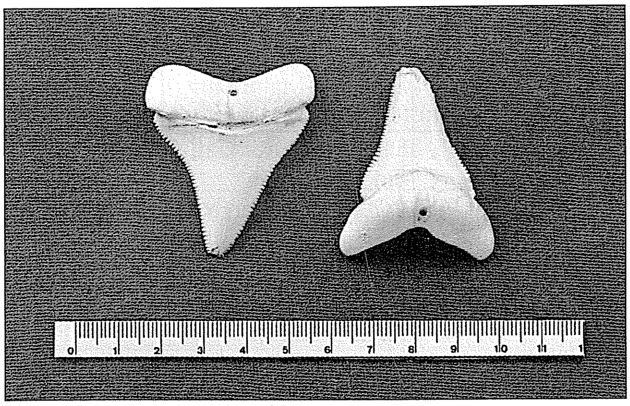

Fig. 2 : Teeth of the great white shark** Carcharodon carcharias **caught in December 1912 in the coastal waters of Vilassar de Mar (Barcelona). (Photo: J. Barrull & I. Mate).

Sl. 2: Zobovje belega morskega volka** Carcharodon carcharias, **ujetega decembra 1912 v obrežnih vodah Vilassarja de Mara (Barcelona). (Foto: J. Barrull & I. Mate).

Tab. 1: Data on great white sharks registered in the Catalonian Sea.
Tab. 1: Podatki o belih morskih volkovih, zabeleženih v Katalonskem morju.

No.	DATE	LOCATION	TL (cm)	W (kg)	SEX	REMARKS	REFERENCE
1	01/1878	Illes Columbrets (Castelló)	500 ca.	2300	?	Capture in nets. Published in "La Ilustración Española y Americana" on January 22nd 1878	Pérez Arcas (1878), Lozano Rey (1928)
2	12/1912	Vilassar de Mar (Barcelona)	471	?	?	Capture in enclosed tuna net. Teeth donated by Dr. Joan Prim on Decembrer 16th 1912. Reg.no.MZB-82-5316 & MZB-82-5317	Barrull & Mate (1993-94)
3	before 1928	Vinaròs (Castelló)	?	?	?	Teeth were deposited in the Museo Nacional de Ciencial Naturales de Madrid. Missing at the present time.	Lozano Rey (1928)
4	before 1928	Cap de ses Salines - Mallorca (Balears)	?	?	?	Capture in a trammel net.	Lozano Rey (1928)
5	1941	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	445	900	?	Capture in enclosed tuna net and harpooned. Pursued to the shore and stranding, was killed with an axe.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
6	08/1941	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	600 ca.	2000	?	Sighting. Turned round the long lines eating the captures.	M. Martínez *(pers. comm.)*
7	08/1941	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	600 ca.	?	?	Sighting. Came with individual no. 6.	M. Martínez *(pers. comm.)*
8	12/1941	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	600	1600	F	Capture in enclosed tuna nets. Stomach content: a head and two legs of goat. Sold for 16.000 pts.	M. Martínez *(pers. comm.)*
9	02-03/1943	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	428	800	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez (*pers. comm.*)
10	02-03/1943	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	523	1500	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez (*pers. comm.*)
11	1958	Badia d'Alcúdia - Mallorca (Balears)	?	?	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez (*pers. comm.*)

12	1960-1970	Cala Blava-Badia de Palma - Mallorca (Balears)	700 ca.	2500	F	Capture in enclosed tuna nets.	Poyatos (*pers. comm.*)
13	1962?	Castelló de la Plana (Castelló)	500	1500	?		Samper (1979), Asensi (1980)
14	1963	Badia d'Alcúdia - Mallorca (Balears)	?	?	?	Capture in enclosed tuna nets. Sold for 17.000 pts.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
15	1967	Cap Ferrutx - Badia d'Alcúdia - Mallorca (Balears)	523	1500	?	Capture in enclosed tuna nets. Stomach content: a dolphin and 4 large tunas.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
16	27/01/1967	Cala Ratjada - Mallorca (Balears)	500	1300	F	Capture in enclosed tuna nets. Sold for 10.000 pts.	M. Martínez *(pers. comm.)*
17	06/1968	Cala Ratjada - Mallorca (Balears)	?	?	?	Capture in enclosed tuna nets.	M. Martínez *(pers. comm.)*
18	02/1969	Badia d'Alcúdia - Mallorca (Balears)	523	1500	?	Capture in enclosed tuna nets. Arrived alive at port.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
19	02/1969	Badia d'Alcúdia - Mallorca (Balears)	428	800	?	Capture in enclosed tuna nets. Jaws preserved.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
20	02/1969	Badia d'Alcúdia - Mallorca (Balears)	?	700e	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
21	01/1970	Ses Caletes des Cap Pinar-Badia de Pollença-Mallorca (Balears)	460	1000	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
22	1971	Sa Foradada - Mallorca (Balears)	550 ca.	1500	M	Capture in enclosed tuna nets.	Poyatos *(pers. comm.)*
23	1972	Cala Murta - Badia de Pollença-Mallorca (Balears)	574	2000	?	Capture in enclosed tuna nets.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
24	02/1976	Cala Murta - Badia de Pollença-Mallorca (Balears)	488	>1200	?	Capture in enclosed tuna nets. Stomach content: half digested ray.	Ramis & Terrasa (1998), M. Martínez *(pers. comm.)*
25	17/11/1992	Platja de la Mar Menuda -Tossa de Mar- (Girona)	475	?	M	Stranding. Jaws preserved at the CRAM (Premià de Mar).	Barrull (1993)
26	08/2000	Cabrera (Balears)	400 ca.	?	?	Sighting. Not absolutely confirmed.	Jiménez (2000), Poyatos *(pers. comm.)*

to be caught accidentally in the enclosed tuna nets at Cap Ferrutx, Ses Caletes des Cap Pinar, S'Illot des Porros, Sa Cova des Bous, and Cala Murta (NE Mallorca) during the same period, but most of them were not documented.

In August 1941, two great white shark were sighted off Ses Caletes des Cap Pinar (Mallorca) (Martínez, *pers. comm.*). Another individual was captured within the same area in December 1941. It was 6 m long and weighing about 1600 kg (Martínez, *pers. comm.*).

On January 27th 1967, a 5 m long great white shark was caught near Cala Ratjada (Mallorca) (Martínez, *pers. comm.*). In early June 1968, one individual was taken at the same locality (Martínez, *pers. comm.*). Fergusson (1996) points out the capture of two individuals in Andratx (Mallorca) in July 1992, adducing a personal comment by J. Piza, veterinary from Marineland Palafolls (Girona). This record is very doubtful for it

Fig. 5: Specimen stranded on November 17th 1992 on Tossa de Mar (Girona) (Photo: J. Moré).
Sl. 5: Osebek, ki je 17. novembra 1992 nasedel na plaži Tossa de Mar (Girona) (Foto: J. Moré).

to the scarce number of records. Encounters are most common at insular sites and in association with pelagic fisheries for large teleosts such as tuna or swordfish.

After the disuse of enclosed tuna nets (at the end of the seventies), occurrences have practically disappeared. Among the studied cases, sixteen were reported with the month of capture. The seasonality of records showed an increase of captures during winter months. It is difficult to discuss the seasonal movements due to the scarcity of data. However, as the great white shark migrate seasonally, and its seasonal migration is at least partially influenced by water surface temperature (Casey & Pratt, 1985), it is possible to predict its presence in the months in which superficial waters of the Catalonian Sea are colder, occurring when the surface temperature is 13° C (Margalef, 1989). The thermal tolerance of this species is demonstrated by its latitudinal distribution (Compagno, 1984). The role played by the surface temperature in affecting this distribution might be even more important to smaller specimens. It is possible that small white sharks have more difficulties in maintaining optimal body temperature in colder waters (Goldman *et al.,* 1996). This would explain the absence, in the study area, of small free-swimming and juvenile individuals during the colder months.

From among the twenty-two cases of white sharks captured, eighteen were caught in enclosed tuna nets (*mandragues*). Most probably they were pursuing the tunas that entered the Mediterranean Sea through the Strait of Gibraltar and went, parallel to the coast, to the laying areas. This is a clearly trophic migratory behaviour. The stomach contents of the Mediterranean white sharks denote predation on bony fish (tuna and swordfish), cartilagineous fish (mainly blue sharks and makos), dolphins and turtles (Fergusson, 1996; Mojetta *et al.,* 1997; De Maddalena, 1999). In the studied area, the number of cases in which great white shark stomach contents were reported, are few. The specimen caught off Cap Ferrutx (Mallorca) (case num. 15) had a dolphin and four large tunas in its stomach. The specimen caught off Cala Murta (Mallorca) (case num. 24) had a half digested ray, while in case No. 6 a head and two legs of a goat were reported. There are three cases (Nos. 5, 6 and 7) in which the sharks were observed during predation on grouper *(Epinephelus guaza),* amberjack *(Seriola dumerilii),* and dolphin fish *(Coryphaena hippurus),* caught in a long-line. Some old fishermen reported of a doll and a dog found in sharks' stomachs (Ramis & Terrasa, 1988). In the Catalonian Sea, the great white shark probably has the same diet as those observed in other parts of the Mediterranean, based primarily on cetaceans, large fishes, and carrion, when occasion arises. Tuna overfishing in the Mediterranean would affect seriously their population (Barrull & Mate, 2000).

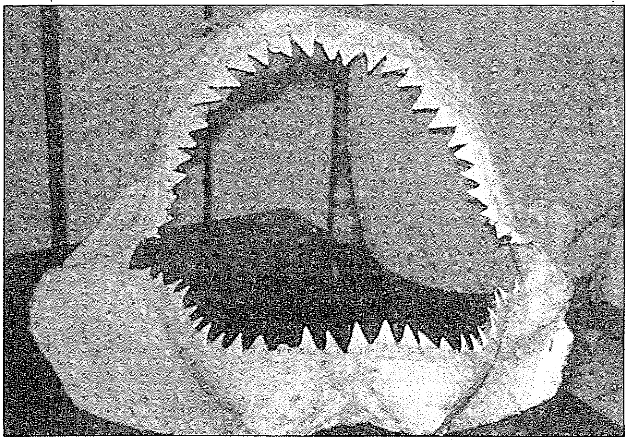

Fig. 6: The jaw of the white shark stranded in Tossa de Mar (Girona). (Photo: J. Barrull & I. Mate).
Sl. 6: Čeljust belega morskega volka, nasedlega na plaži Tossa de Mar (Girona). (Foto: J. Barrull & I. Mate).

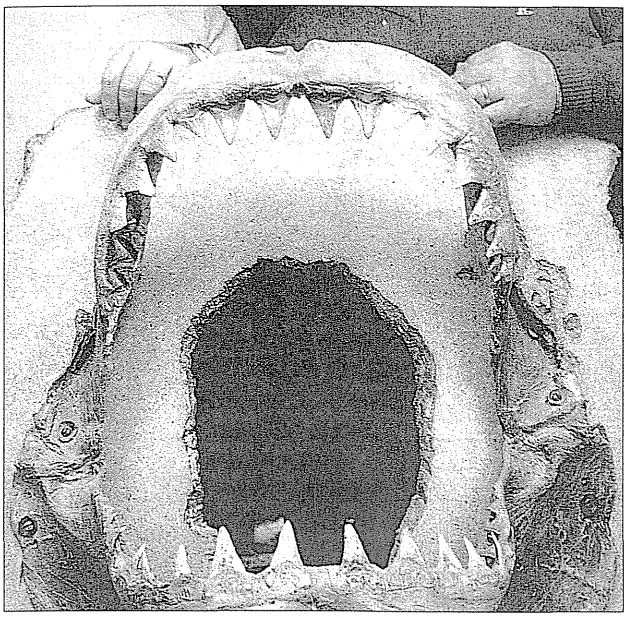

Fig. 3: The jaw of the 800 kg white shark caught in February 1969 off Badia d'Alcúdia (Mallorca). (Photo: S. Terrasa).
Sl. 3: Čeljust 800 kg težkega belega morskega volka, ujetega februarja 1969 v bližini Badie d'Alcúdie (Mallorca). (Foto: S. Terrasa).

seems that Mr. Piza has never been asked about the matter, and nobody in Port d'Andratx could confirm these catches (Martínez, *pers. comm.).*

Barrull (1993) and Barrull & Mate (1996) report on the stranding of a 475 cm long male on November 17th 1992 on the Mar Menuda beach in Tossa de Mar (Girona) (Figs. 5, 6). The individual was swimming slowly for at least six hours just below the surface of coastal shallow waters. After midnight the animal was stranded moribund on the beach, dying an hour later (Alegre, *pers. comm.).* The uncertain fact regarding this record is the total length of the animal, since the members of CRAM (Centre de Recuperació d'Animals Marins) and Marineland Palafolls (Girona) who examined the shark did not measure it with due precision, so that the total length of the specimen could be anything from 475 to 520 cm (Alegre, *pers. comm.).*

In early August 2000, a large white shark was sighted by fishermen, at nightfall, swimming near their boat. The estimated length was nearly 400 cm (Jiménez, 2000). The Guardia Civil patrol that proceeded to the place of sighting could not confirm the sighting (Poyatos, *pers. comm.).*

Fergusson (1996) points out the capture of an individual near Tarragona, without any additional data, making reference to the work by De Buen (1926). This record cannot be considered valid either, for the article by De Buen is a general listing of fishes observed off the coast of Morocco and the Balearic Islands and, moreover, the species *C. carcharias* is not reported in it.

DISCUSSION

In the Catalonian Sea, the great white shark seems to prefer the waters of the offshore islands (a total of 21 cases are referred to Balearic Islands), just as established in other places of the Mediterranean. This species can be regarded primarily a coastal shark occurring in waters of the continental shelf, at depths ranging between 200 m and less than 20 m.

Although Quignard & Raibaut (1993) point out that the populations of this species have increased in the Gulf of Lion (near the study area) it is likely only an occasional, transient inhabitant of the Catalonian Sea, due

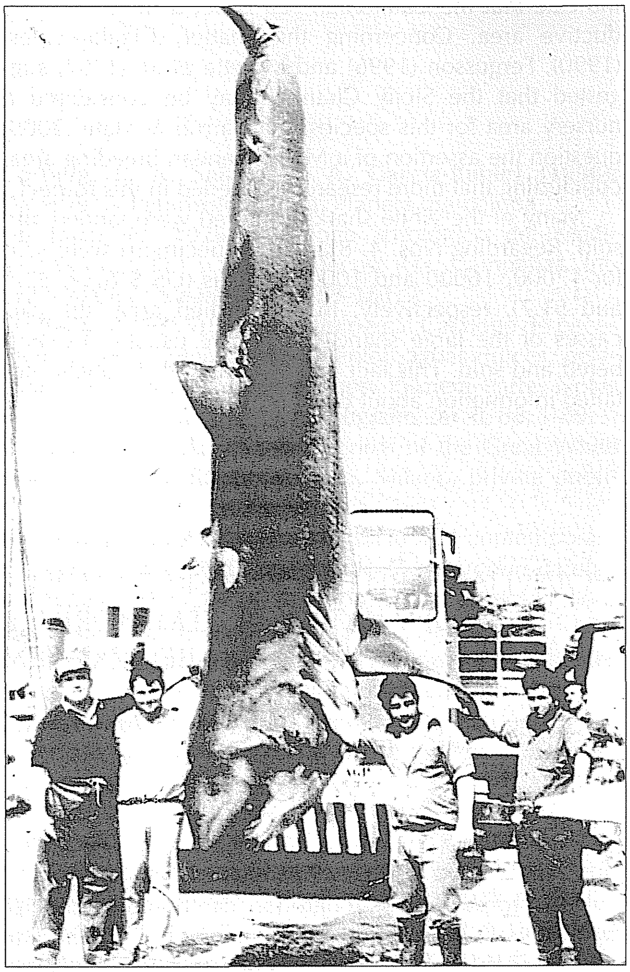

Fig. 4: One of the three individuals caught in February 1969 in the waters off Badia d'Alcúdia (Mallorca). (Photo: courtesy of "Brisas").
Sl. 4: Eden od treh osebkov, ujetih februarja 1969 v obrežnih vodah Badie d'Alcúdie (Mallorca). (Foto: z dovoljenjem revije "Brisas").

The size of sharks was reported in many cases, but the manner by which lengths were obtained is often unknown. Solely it is possible to suggest that the average of total length for the recorded specimens ranges from 426 cm to 600 cm. The dimensions of the registered sharks indicate that they were subadults and adults, since they reached the sizes given in bibliography for these development stadiums (Francis, 1996; Pratt, 1996). Only in five cases the sex of the specimens was reported: three of them were females and two were males. With so few data it is not possible to find evidence about sexual segregation in the area. There is a total absence of records of small free-swimming and juvenile individuals, although small white sharks could be confused with *Isurus* species by fishermen. Neither have there been any cases of pregnant females, and no phenomena related with reproduction. Everything seems to indicate that the Catalonian Sea is not a suitable reproductive area. Concerning this matter, Cigala-Fulgosi (1990), Fergusson (1996) and Mojetta *et al.* (1997) suggested that the Sicily Channel may be considered a nursery area for this species, but Barrull & Mate (2000) question the assertion of a Mediterranean breeding area, concluding that more research is needed in this respect.

Many of the white sharks captured were landed and sold. Regarding Nos. 4, 8 and 16, specimens were sold for 17000, 16000 and 10000 pesetas (US $ 87.9, 82.7 and 51.7), respectively. In the studied area, the carcasses of the large sharks caught are usually dismembered and sold. This fact makes it difficult to obtain detailed information about these animals.

No injuries or fatal attacks on humans have been reported so far. Obviously, fortuitous encounters with this species in the Catalonian Sea are extremely unlikely.

CONCLUSIONS

Great white shark is very likely merely an occasional and transient inhabitant of the Catalonian Sea. It seems to prefer the waters of the offshore islands. The seasonality of records showed an increase during the months of winter, when they are in search for colder waters. Usually, their occurrence is closely associated with pelagic fisheries. In the Catalonian Sea they feed primarily on tunas, dolphins, rays and carrion. All individuals reported are large specimens, adults or subadults. No injurious or fatal attacks on humans are attributable to this species in the studied area. The authors wish to underline the importance of a continual collecting of new and historical data on the occurrence of the great white shark in the Catalonian Sea, as this may contribute towards a better understanding of this species.

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POJAVLJANJE BELEGA MORSKEGA VOLKA *CARCHARODON CARCHARIAS* LINNAEUS, 1758) V KATALONSKEM MORJU (SZ SREDOZEMLJE): PREGLED ZAPISOV IN BELEŽKE O NJEGOVI EKOLOGIJI

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POVZETEK

Beli morski volk Carcharodon carcharias *(Linnaeus, 1758) je kozmopolitska vrsta, živeča v obrežnih zmerno toplih vodah. V Sredozemlju je omenjana v splošni ihtiološki literaturi, zabeležena pa je tudi v lokalnih favnističnih kompilacijah. Pričujoči članek obravnava pojavljanje belega morskega volka v Katalonskem morju z revizijo podatkov, zabeleženih v zvezi s to vrsto v tem območju. Zbrane informacije obsegajo 26 osebkov, opaženih ali ujetih med letoma 1878 in 2000. Pérez Arcas (1878) navaja ujetje enega osebka leta 1878 v bližini Valencije med otoki Columbretes in Castellójem, kar je bil brez dvoma prvi dokumentirani zapis v Katalonskem morju o tej vrsti. Tudi Lozano Rey (1928) omenja belega morskega volka, ujetega leta 1878, in glede na njegov opis gre verjetno za osebek, o katerem je poročal že Arcas. Barrull & Mate (1993-1994, 1996) opisujeta osebek, ki se je decembra 1912 ujel v mrežo tunaro v bližini Vilassarja de Mara (Barcelona). Samper (1979) opozarja na ujetje samice v bližini*

Castellója, najbrž v letu 1962. Ramis & Terrasa (1988) navajata 18 osebkov, ujetih s tunaro v bližini Balearskih otokov med letoma 1941 in 1976. Barrull (1993) in Barrull & Mate (1996) poročata o samcu, ki je 17. novembra 1992 nasedel na plaži Mar Menuda v Tossi de Mar (Girona). Nekateri podatki iz literature (Asensi, 1980; Corbera et al., *1996; Fergusson, 1996) so bili na novo pregledani in analizirani, ne pa tudi potrjeni.*

Kar zadeva Katalonsko morje, se zdi, da se beli morski volk najraje zadržuje v otoških vodah (21 opažanj je iz območij Balearskih otokov). Sezonskost zapisov kaže na njihovo povečano pojavljanje v zimskih mesecih, ko beli morski volkovi iščejo hladnejše vode. Sicer pa je njihovo pojavljanje največkrat povezano z ribarjenjem na odprtem morju. V Katalonskem morju se prehranjujejo s tunami, delfini, ražami in, če le mogoče, z mrhovino. V vseh primerih so bili opaženi ali ujeti bolj ali manj odrasli osebki. Zabeležen ni bil niti en sam svobodno plavajoči mladostni osebek, kot tudi ne breja samica ali kar koli, kar bi lahko povezali z razmnoževanjem. Tako vse kaže, da Katalonsko morje ni primerno razmnoževalno okolje za to vrsto. Belemu morskemu volku niso bili pripisani nobeni pogubni napadi na človeka v raziskovanem območju. Avtorja opozarjata na velik pomen nadaljnjega zbiranja novih in zgodovinskih podatkov o pojavljanju belega morskega volka v Katalonskem morju, saj bi to lahko pripomoglo k veliko boljšemu poznavanju te vrste.

Ključne besede: beli morski volk, *Carcharodon carcharias*, Katalonsko morje, zapisi, ekologija

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IN RELATION TO THE CAPTURES OF A GREAT WHITE SHARK, *CARCHARODON CARCHARIAS* (LINNAEUS, 1758), AND A SHORTFIN MAKO, *ISURUS OXYRINCHUS* RAFINESQUE, 1809, IN THE MESSINA STRAIT

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ABSTRACT

We developed a critical revision of some incorrect data recently reported by Fergusson et al. *(2000) in relation to the two captures of sharks in the waters near Ganzirri (Messina Strait, Italy) and their stomach contents. A specimen caught in 1963, reported by Fergusson* et al. *(2000) as a white shark* Carcharodon carcharias *having in its stomach a marine turtle* Caretta caretta, *was in fact a shortfin mako* Isurus oxyrinchus *having in the stomach a bow-net and some buttons. The other, a white shark caught in 1965, had in its stomach remains of marine turtle* Caretta caretta, *and not an ocean sunfish* Mola mola *as erroneously reported by Fergusson* et al. *(2000).*

Key words: *Carcharodon carcharias, Isurus oxyrinchus, Caretta caretta, Mola mola,* Mediterranean Sea

IN RELAZIONE ALLE CATTURE DI UNO SQUALO BIANCO, *CARCHARODON CARCHARIAS* (LINNAEUS, 1758), E DI UNO SQUALO MAKO DALLE PINNE CORTE, *ISURUS OXYRINCHUS* RAFINESQUE, 1809 NELLO STRETTO DI MESSINA

SINTESI

Viene svolta la revisione critica di alcuni dati erronei recentemente riportati da Fergusson et al. *(2000) in relazione a due catture di squali nelle acque di Ganzirri (Stretto di Messina, Italia) ed ai loro contenuti stomacali. Un esemplare catturato nel 1963, riportato da Fergusson* et al. *(2000) come uno squalo bianco* Carcharodon carcharias *avente nello stomaco una tartaruga marina* Caretta caretta, *era in realtà uno squalo mako dalle pinne corte* Isurus oxyrinchus *avente nello stomaco una nassa e dei bottoni. L'altro, uno squalo bianco preso nel 1965, aveva nello stomaco resti di tartaruga marina* Caretta caretta, *e non un pesce luna* Mola mola *come erroneamente riportato da Fergusson* et al. *(2000).*

Parole chiave: *Carcharodon carcharias, Isurus oxyrinchus, Caretta caretta, Mola mola,* Mare Mediterraneo

INTRODUCTION

Fergusson *et al.* (2000) recently presented an analysis of some cases of predation by white sharks, *Carcharodon carcharias* (Linnaeus, 1758), upon marine turtles in the Mediterranean Sea, including the case reported as the first record of predation (or scavenging) by white shark upon ocean sunfish, *Mola mola* (Linnaeus, 1758). Since in this work we noticed remarkable inexactness regarding the two captures of sharks in 1963 and 1965 in the Messina Strait, we decided to present herewith the direct report by Nicola Donato, who was the author of both these captures.

RESULTS AND DISCUSSION

In relation to a shortfin mako, *Isurus oxyrinchus* Rafinesque, 1809, caught in June 1963

In Fergusson *et al.* (2000) there is a detailed report of the capture of a shark indicated to be a 350 cm TL white shark, harpooned ca. 3 km offshore from Ganzirri in June 1963. Fergusson *et al.* (2000) wrote that in its stomach remains of a marine turtle, *Caretta caretta* (Linnaeus, 1758), were found and they furnished precise details of the damage sustained by the carapace as a consequence of the shark's bite. Strangely, Fergusson *et al.* (2000) specify several times to have collected this testimony directly from the author of the shark capture, Nicola Donato (that is also a co-author of the present work), as personal communication to Ian K. Fergusson and Mark A. Marks. This statement is not true, and the report about the species of shark and its stomach contents is inexact. It is curious to note that Mojetta *et al.* (1997) mentioning the same specimen wrote that it had a dolphin in its stomach, indicating a personal communication of Ian K. Fergusson as the source of this data.

For this reason we decided to expose the true report of this capture. The shark in question was in fact a shortfin mako, *Isurus oxyrinchus* Rafinesque, 1809, and not a white shark. The specimen was sighted some hundreds of meters offshore from Contrada Principe (Ganzirri), it was approached with a mid-sized boat, and when it was harpooned by Nicola Donato it reacted violently. Once captured, neither a marine turtle as written by Fergusson *et al.* (2000) nor a dolphin as indicated by Mojetta *et al.* (1997) was found in its stomach, but a small bow-net, similar in shape to those used for capturing lobsters, beside some large buttons sewed on pieces of a dark cloth, apparently coming from the kind of coat commonly worn by seamen. The specimen was never measured but it was estimated by Donato to be about 320 cm long and weighing about 250 kg.

In relation to a great white shark, *Carcharodon carcharias* (Linnaeus, 1758), caught on March 9th 1965

Again, Fergusson *et al.* (2000) reported on another case, claimed as the first record of predation (or scavenging) by white shark upon ocean sunfish, *Mola mola*. The authors refer to the capture of a more than 500 cm TL great white shark on March 9th 1965, taken near Ganzirri and again performed by Nicola Donato. Fergusson *et al.* (2000) report that the shark was first observed near the breakwater by Donato with its boat some 100 m offshore and then harpooned. In its stomach was a freshly-ingested adult ocean sunfish, *Mola mola*, measuring about 2 m TL, bitten into three sections (head, mid-trunk and posterior with dorsal fin, anal fin and clavus). As in the previous case, Fergusson *et al.* (2000) in

Fig. 1: Nicola Donato showing the set of jaws of the great white shark, *Carcharodon carcharias* ***(Linnaeus, 1758), caught by him near Ganzirri (Sicily, Italy) on March 9th 1965. (Photo: A. Celona).***
Sl. 1: Nicola Donato med razkazovanjem čeljusti belega morskega volka *Carcharodon carcharias* ***(Linnaeus, 1758), ujetega 9. marca 1965 v bližini Ganzirrija (Sicilija). (Foto: A. Celona).***

dicate the source of the data to be a personal communication of Nicola Donato to Ian K. Fergusson and Mark A. Marks; but this is not true, and this second report, too, is incorrect.

The truth as far as this capture is concerned is the following. The white shark was first observed pursuing a school of mullets, *Mugil* sp., only a few meters from the shore, in very shallow waters, where it almost touched the sea-bottom with the ventral surface of its body, while its dorsal part was out of the water. As the shark moved towards offshore waters, it was followed by the boat. It was quickly caught and Nicola Donato harpooned it about 40 meters from the coast. The harpoon penetrated through the posterior part of the trunk, at about mid-point between the first dorsal fin and the caudal fin. The shark hauled the boat for about four hours, crossing the Messina Strait three times before dying. In its stomach several parts of marine turtle, *Caretta caretta*, were found, as well as remains of bony fishes and other unidentified remains. The measurements on this specimen were taken by Prof. Sebastiano Genovese of the University of Messina, who stated the length at 620 cm and the weight of 1200 kg. This weight is also indicated on a plate fixed on the set of jaws preserved in Ganzirri, in the Istituto di Idrobiologia dell'Università di Messina (Fig. 1).

This capture was reported previously by the following authors: Anonymous (1965), Berdar & Riccobono (1986), Giudici & Fino (1986), Fergusson (1996), Mojetta *et al.* (1997) and De Maddalena (1999). Mojetta *et al.* (1997) were the first to report correctly that the stomach of this specimen contained remains of marine turtle, but they wrongly indicated that the capture was made on 1st April. About the size of the shark, Anonymous (1965) report a length of 5 m, a weight of 8 q and a first dorsal fin height of 160 cm, while Berdar & Riccobono (1986) reports a length of 620 cm, a pectoral fin length of 120 cm and a first dorsal fin height of 160 cm; the first dorsal fin height reported by both sources is clearly unacceptable, while the weight of 8 q has to be referred to the gutted and beheaded specimen. On the basis of the two photographic evidences examined by the authors (Fig. 2), the total length of the specimen could be something less than the reported one, apparently around 560 cm, and it seems reasonable to infer that the reported 620 cm length was obtained measuring the shark over the curve of the body instead of in a straight line. This could also explain the relatively low weight. Unfortunately it was not possible to gather more information about the shark in question, since Sebastiano Genovese and Adolfo Berdar are no longer with us.

The jaws were examined by the authors and the measurements on the upper and lower anterior teeth were taken following Mollet *et al.* (1996) (Tab. 1). Teeth rows are 12-12 above and 12-12 below.

Tab. 1: Measurements of the upper and lower anterior teeth of the great white shark, *Carcharodon carcharias* ***(Linnaeus, 1758), caught near Ganzirri on March 9th 1965.***

Tab. 1: Mere zgornjih in spodnjih sprednjih zob belega morskega volka *Carcharodon carcharias* ***(Linnaeus, 1758), ujetega blizu Ganzirrija 9. Marca 1965.***

First upper anterior tooth enameloid height (UA1E1)	31 mm
First upper anterior tooth enameloid width (UA1EW)	40 mm
Second upper anterior tooth enameloid height (UA2E1)	28 mm
Second upper anterior tooth enameloid width (UA2EW)	39 mm
First lower anterior tooth enameloid height (LA1E1)	22 mm
First lower anterior tooth enameloid width (LA1EW)	26 mm
Second lower anterior tooth enameloid height (LA2E1)	33 mm
Second lower anterior tooth enameloid width (LA2EW)	30 mm

CONCLUSIONS

With this work we feel to have definitely clarified the series of mistakes that accompanied the reports of these two captures in the previous literature. Concerning the ocean sunfish, remains of this animal, belonging to small specimen (20-30 kg in weight), have been found on some occasions in the stomachs of blue sharks, *Prionace glauca* (Linnaeus, 1758), caught in the Messina Strait but, to our knowledge, never in specimens of *Carcharodon carcharias*.

Fig. 2: Great white shark, *Carcharodon carcharias* ***(Linnaeus, 1758), caught by Nicola Donato near Ganzirri (Sicily, Italy) on March 9th 1965. (Photo reproduced by kind permission of Antonino Donato).***

Sl. 2: Beli morski volk *Carcharodon carcharias* ***(Linnaeus, 1758), ki ga je 9. marca 1965 ujel Nicola Donato v bližini Ganzirrija (Sicilija). (Reprodukcija fotografskega posnetka s prijaznim dovoljenjem Antonina Donata).***

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V ZVEZI Z UJETJEM BELEGA MORSKEGA VOLKA *CARCHARODON CARCHARIAS* (LINNAEUS, 1758) IN ATLANTSKEGA MAKA *ISURUS OXYRINCHUS* RAFINESQUE, 1809 V MESSINSKEM PRELIVU

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POVZETEK

Avtorji pričujočega članka želijo napraviti kritični pregled (napačnih) podatkov v poročilu Fergussona et al. *(2000) v zvezi z ujetjem dveh morskih psov v vodah blizu Ganzirrija (Messinski preliv, Italija) in vsebino njunih želodcev. V letu 1963 ujeti pes, ki naj bi bil po poročanju Fergusona* et al. *(2000) beli morski volk* Carcharodon carcharias *s kareto* Caretta caretta *v želodcu, je bil v resnici atlantski mako* Isurus oxyrinchus *z majhno vršo in nekaj gumbi v želodcu. Drugi pes - beli morski volk, ujet leta 1965 – je imel v želodcu ostanke karete* Caretta caretta, *ne pa morskega meseca* Mola mola, *kot so napačno poročali Fergusson* et al. *(2000).*

Ključne besede: *Carcharodon carcharias, Isurus oxyrinchus, Caretta caretta, Mola mola,* Mediterranean Sea

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MORPHOMETRICS OF NEONATE VELVET BELLY, *ETMOPTERUS SPINAX* (LINNAEUS, 1758)

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ABSTRACT

Biological details on four neonates of the velvet belly, Etmopterus spinax *(Linnaeus, 1758), caught at the beginning of 2000 at Viareggio (Ligurian Sea), are reported. The specimens, two females and two males, measured 108 mm, 110 mm, 142 and 153 mm in length. Morphometrics of these specimens is presented. Captures of these specimens occurred near Viareggio, suggesting that this region may be a nursery area for* E. spinax.

Key words: velvet belly, *Etmopterus spinax*, reproduction, Ligurian Sea

MORFOMETRIA DEL NEONATO DI MORETTO, *ETMOPTERUS SPINAX* (LINNAEUS, 1758)

SINTESI

Viene segnalata la cattura di quattro piccoli di moretto, Etmopterus spinax *(Linnaeus, 1758), pescati a Viareggio (Mar Ligure) all'inizio del 2000. Gli esemplari, 2 femmine e 2 maschi, presentavano lunghezze totali pari a 108 mm, 110 mm, 142 mm e 153 mm. Dei quattro esemplari vengono esposti completi rilevamenti morfometrici. Varie catture di piccoli appena nati registrate presso Viareggio suggeriscono che questa zona sia una nursery area per* E. spinax.

Parole chiave: moretto, *Etmopterus spinax*, riproduzione, Mar Ligure

INTRODUCTION

The velvet belly, *Etmopterus spinax* (Linnaeus, 1758) is a small selachian of the family Etmopteridae Fowler 1934, characterized principally by the presence of two grooved dorsal spines (the second longer than the first), lack of the anal fin, and by the presence of photophores distributed in specific patterns on the ventral surface (Fig. 1). The upper teeth have five cusps and the lower teeth are bladelike and unicuspidate. The denticles have a long, slender and slightly grooved crown (Tortonese, 1956). This species rarely exceeds 45 cm in length, but it may reach lengths of at least 60 cm and possibly as much as 115 cm (Cadenat & Blache, 1981; Compagno, 1984; Bauchot, 1987). *E. spinax* matures at a length between 280 and 360 mm, and is ovoviviparous, with litters of 6-20 pups (Compagno, 1984; Bauchot, 1987). Parturition occurs year-round (Vacchi & Relini Orsi, 1979) and the size at birth is 120 to 140 mm (Compagno, 1984) or 100 to 110 mm (Vacchi & Relini Orsi, 1979; Bauchot, 1987; Barrull *et al.*, 1999). Its diet is composed of small fishes, squids and crustaceans (Compagno, 1984). This species lives near or above the bottom on the outer continental shelf and upper lope usually at depths between 200 and 500 m (Compagno, 1984). The velvet belly's distribution includes the Mediterranean Sea and almost all of the eastern Atlantic, from Iceland and Norway to Morocco, Senegal, Sierra Leone, from Ivory Coast to Nigeria, from Cameroon to Gabon, Azzorre, Cape Verde Islands, South Africa (Bigelow & Schroeder, 1957; Compagno, 1984). *E. spinax* is occasionally caught in bottom and pelagic trawls, and utilized for fishmeal, for liver oil, and rarely for human consumption (fresh or dried), except in Morocco, where it can be found often at the fishmarkets (Compagno, 1984; Bauchot, 1987). Morphometrics of five specimens ranging from 153 to 204 mm in total length (TL) were recently reported in Kabasakal & Unsal (1999).

Morphometric measurements of four young *E. spinax* are presented herein, with the purpose to contribute to the knowledge of the velvet belly's morphology and to furnish an additional instrument for the recognition of the species of the genus *Etmopterus*.

MATERIALS AND METHODS

In the beginning of 2000, four small specimens of velvet belly were acquired at the fish market in Milano, Italy, where they had been transported following their capture at Viareggio (Ligurian Sea, Italy) (Fig. 2). The four captured *E. spinax* were examined, and complete morphometric measurements made following Compagno (1984), adding D1S (first dorsal spine length) and D2S (second dorsal spine length). The specimens were preserved in 70% ethyl alcohol.

RESULTS

The lengths of these small sharks, two females and two males, were 108 mm, 110 mm, 142 mm and 153 mm, respectively. Their coloration presented no particular differences from that observable in adults of this species, and was similar in all four specimens. The dorsal surface was brown, while the ventral surface was largely black (from the underside of the snout to the pelvic region), with a narrow pale stripe on the side of the head behind the mouth. Conspicuous black marks were present even on dorsal anterior and inner margins, upper and lower caudal lobe, caudal peduncle, and anal fins. All posterior fin margins were white-edged and indented. The upper teeth had cusplets considerably smaller than in adults of the species. Complete morphometric measurements of the four specimens are presented in table 1.

DISCUSSION

The small size of the four specimens examined clearly indicated they were neonates. Lengths of two of the specimens were 10 and 12 mm less than the minimum size at birth indicated by Compagno (1984), supporting Vacchi & Relini Orsi (1979), Bauchot (1987) and Barrull *et al.* (1999) observations, indicating that the size at birth of *E. spinax* is between 100 and 110 mm.

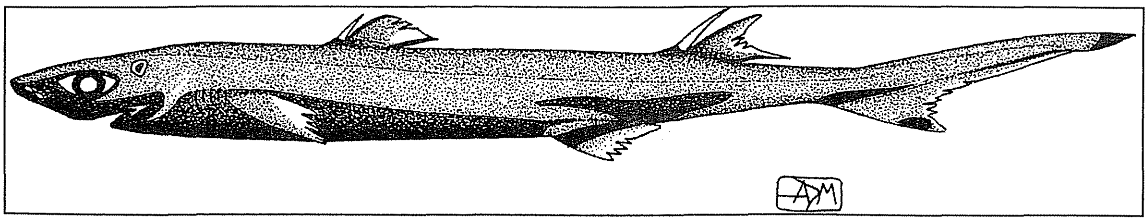

Fig. 1: Neonate velvet belly, *Etmopterus spinax* ***(Linnaeus, 1758). (Drawing by A. De Maddalena)***
Sl. 1: Novoskoteni črni trnež *Etmopterus spinax* ***(Linnaeus, 1758). (Risba: A. De Maddalena)***

During 1999-2000, at least 10 other neonates of this species had been transported to the fish market in Milano, following capture at the same locality, Viareggio. It appears that the region near Viareggio may be a nursery area for the velvet belly, which is in accord with observations made by Vacchi & Relini Orsi (1979) regarding the importance of the Ligurian Sea for reproduction of this species. That no adult female velvet belly has been collected from this region can be explained by the fact that this species is not retained by commercial fishermen. It is very probable that adult *E. spinax* are released after capture (as reported by Costa, 1991), while sometimes the neonates are casually transported to fish markets in crates containing other fishes.

ACKNOWLEDGEMENTS

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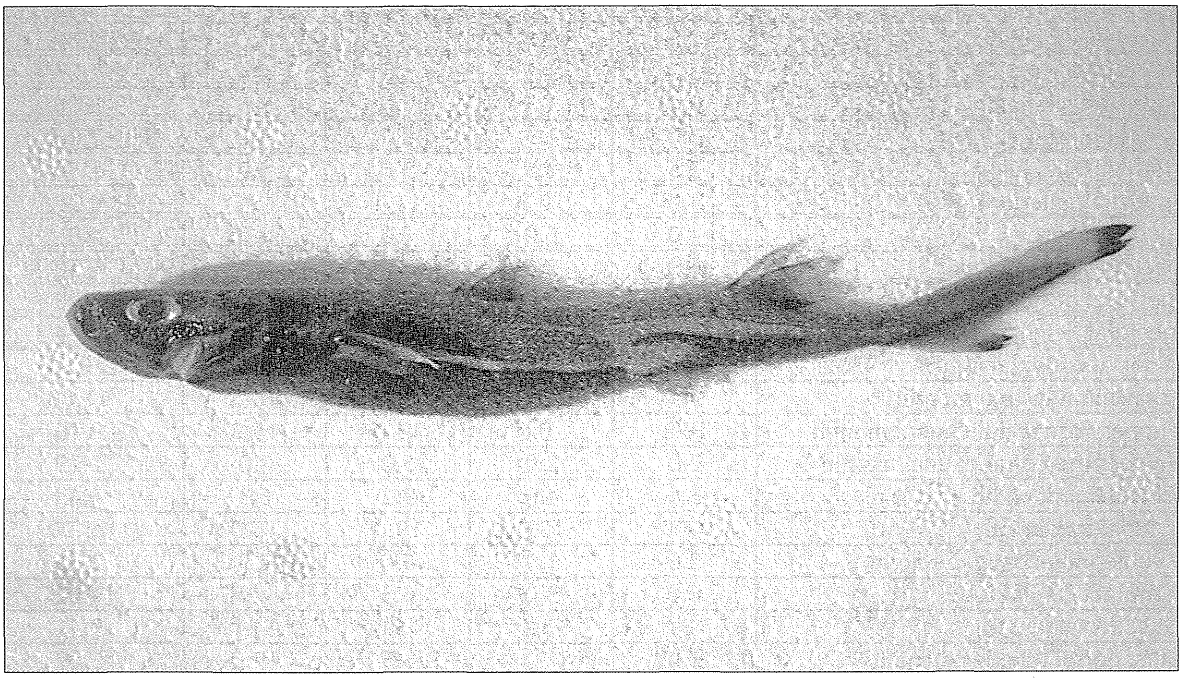

Fig. 2: Neonate velvet belly, *Etmopterus spinax* ***(Linnaeus, 1758), caught at Viareggio, Italy, in 2000. (Photo: L. Piscitelli)***
Sl. 2: Novoskoteni črni trnež *Etmopterus spinax* ***(Linnaeus, 1758), ujet leta 2000 v bližini Viareggia v Italiji. (Foto: L. Piscitelli)***

Tab. 1: Morphometrics of the four neonate *Etmopterus spinax* ***(Linnaeus, 1758). All measurements are given in millimetres.***
Tab. 1: Morfometrija štirih novoskotenih črnih trnežev *Etmopterus spinax* ***(Linné, 1758). Vse mere so v milimetrih.***

Measurements	#1	#2	#3	#4	%TOT (mean)
TOT total length	108.0	110.0	142.0	153.0	100.00
FOR fork length	91.0	93.0	124.8	127.0	84.92
PRC precaudal length	81.0	85.0	104.5	119.0	75.91
PD2 pre-second dorsal length	62.0	62.0	86.0	89.0	58.12
PD1 pre-first dorsal length	34.0	36.0	51.0	48.0	34.12
HDL head length	24.0	26.0	33.5	38.0	23.57
PG1 prebranchial length	19.5	20.0	26.5	27.0	18.13
PSP prespiracular length	14.0	16.0	18.5	19.0	13.24
POB preorbital length	4.5	5.0	6.5	7.0	4.46
PPI prepectoral length	24.0	26.0	33.5	38.0	23.57

PP2 prepelvic length	56.0	57.0	74.0	77.0	51.53
SVL snout-vent length	61.0	61.0	79.0	83.0	55.45
IDS interdorsal space	20.5	20.0	27.4	32.5	19.42
DCS dorsal-caudalspace	9.5	12.8	15.0	20.0	11.02
PPS pectoral-pelvic space	18.0	24.5	35.0	38.0	22.11
PCA pelvic-caudal space	17.0	17.0	24.6	26.0	16.37
VCL vent-caudal length	47.0	49.0	63.0	70.0	44.54
PRN prenarial length	1.2	1.3	2.6	2.0	1.36
POR preoral length	9.7	13.0	12.5	15.0	9.85
EYL eye length	6.6	9.2	9.8	9.0	6.81
EYH eye height	4.4	3.8	3.0	5.20	3.26
ING intergill length	4.0	6.0	7.0	11.0	5.32
GS1 first gill slit height	2.5	1.8	3.5	3.0	2.09
GS2 second gill slit height	3.0	1.5	3.5	2.5	2.06
GS3 third gill slit height	3.0	1.5	3.5	2.5	2.06
GS4 fourth gill slit height	3.0	1.5	3.5	2.2	2.06
GS5 fifth gill slit height	2.5	1.5	3.0	2.0	1.85
P1A pectoral anterior margin	10.6	10.3	11.4	15.0	9.25
P1B pectoral base	4.0	6.0	7.0	8.0	4.83
P1I pectoral inner margin	6.0	7.0	6.0	9.0	5.50
P1P pectoral posterior margin	4.0	3.0	4.0	6.0	3.29
PIH pectoral height	7.0	9.0	15.0	18.0	9.24
CDM dorsal caudal margin	26.8	22.7	30.2	29.7	21.53
CPV preventral caudal margin	14.0	12.0	18.0	16.8	11.88
CPU upper postventral caudal margin	10.3	10.0	14.0	15.8	9.70
CPL lower postventral caudal margin	2.0	2.0	5.0	3.0	2.29
CFW caudal fork width	5.5	4.0	9.2	6.3	4.83
CFL caudal fork length	14.0	13.0	19.0	15.0	11.99
CSW subterminal caudal margin	2.6	1.9	5.0	2.9	2.39
CTL terminal caudal lobe	6.0	5.0	6.3	7.2	4.82
D1L first dorsal length	10.0	11.0	13.0	14.1	9.41
D1A first dorsal anterior margin	7.0	7.0	8.5	12.0	6.67
D1B first dorsal base	6.0	6.8	6.5	8.0	5.38
D1H first dorsal height	3.0	2.9	4.6	5.0	2.98
D1I first dorsal inner margin	4.0	4.2	6.5	6.1	4.02
D1P first dorsal posterior margin	2.0	4.0	6.0	2.5	2.83
D1S first dorsal spine	7.0	6.0	6.2	7.0	5.22
D2L second dorsal length	12.0	15.0	17.0	17.5	12.04
D2A second dorsal anterior margin	12.0	7.2	16.7	15.0	9.80
D2B second dorsal base	6.5	9.0	12.0	11.0	7.46
D2H second dorsal height	3.5	4.0	7.0	6.0	3.93
D2I second dorsal inner margin	5.5	6.0	5.0	6.5	4.11
D2P second dorsal posterior margin	4.0	3.0	8.0	4.0	3.67
D2S second dorsal spine	10.0	11.0	10.8	>5.0	8.98
P2L pelvic length	9.0	11.3	13.5	17.0	9.80
P2A pelvic anterior margin	7.0	5.0	7.0	10.0	5.62
P2B pelvic base	7.0	7.8	8.0	8.5	6.19
P2H pelvic height	3.5	2.5	4.5	4.5	2.90
P2I pelvic inner margin length	2.0	3.5	5.5	8.5	3.60
P2P pelvic posterior margin length	4.5	5.0	8.0	8.5	4.96
HDH head height	10.0	8.0	14.0	9.0	8.07
TRH trunk height	10.5	8.0	12.0	8.5	7.73

ABH abdomen height	9.8	7.0	11.0	11.0	7.59
TAH tail height	7.2	6.5	9.5	9.0	6.29
CPH caudal peduncle height	3.0	3.5	5.0	4.5	3.10
DPO 1st dorsal midpt.-pelvic origin	13.0	15.0	18.0	20.0	12.86
PDI pelvic midpt.-1st dorsal insertion	16.0	18.5	24.8	29.0	17.01
PDO pelvic midpt.-2nd dorsal origin	4.0	1.5	2.6	2.5	2.13
MOL mouth length	3.5	3.8	4.0	4.0	3.03
MOW mouth width	8.0	9.0	9.0	10.0	7.12
NOW nostril width	3.5	2.8	4.0	3.8	2.77
INW internarial space	2.8	3.5	4.4	4.0	2.87
ANF anterior nasal flap length	0.7	1.2	1.0	1.1	0.79
CLO clasper outer length	X	X	2.0	2.0	1.36
CLI clasper inner length	X	X	6.0	7.5	4.56
CLB clasper base width	X	X	1.0	1.0	0.67
INO interorbital space	10.8	12.0	13.0	13.2	9.67
SPL spiracle length	1.3	1.3	1.5	2.5	1.27
ESL eye spiracle space	2.2	1.0	2.0	1.5	1.33
HDW head width	13.0	14.0	17.0	18.0	12.12
TRW trunk width	9.5	9.0	12.0	12.0	8.32
ABW abdomen width	7.5	7.0	10.5	11.0	6.97
TAW tail width	5.0	3.5	7.0	7.0	4.33
CPW caudal peduncle width	2.3	2.2	3.0	2.6	1.98

MORFOMETRIJA NOVOSKOTENIH ČRNIH TRNEŽEV *ETMOPTERUS SPINAX* (LINNAEUS, 1758)

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POVZETEK

Avtorja navajata biološke podatke o štirih novoskotenih črnih trnežih Etmopterus spinax *(Linnaeus, 1758), ujetih v začetku leta 2000 v bližini Viareggia (Ligursko morje). Osebki (dva samca in dve samici) so bili dolgi 108, 110, 142 in 153 mm. Predstavljena je morfometrija vseh štirih trnežev. Avtorja sklepata, da je ta del morja v bližini Viareggia razmnoževalno okolje za to vrsto morskega psa.*

Ključne besede: črni trnež, *Etmopterus spinax*, razmnoževanje, Ligursko morje

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FIRST CONFIRMED RECORD OF ANGULAR ROUGHSHARK *OXYNOTUS CENTRINA* (LINNAEUS, 1758) PREDATION ON SHARK EGG CASE OF SMALL-SPOTTED CATSHARK *SCYLIORHINUS CANICULA* (LINNAEUS, 1758) IN MEDITERRANEAN WATERS

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ABSTRACT

The stomach content examination of two male angular roughshark individuals Oxynotus centrina *captured in Barcelona's coastal waters on November 2000 and January 2001 revealed the presence of yolk sacks and embryos from the small-spotted catshark* Scyliorhinus canicula. *Up to date, this is the first confirmed record of small-spotted catshark egg predation in the Mediterranean waters.*

Key words: *Oxynotus centrina, Scyliorhinus canicula,* predation, shark egg case, embryos, Mediterranean Sea

PRIMA SEGNALAZIONE CONFERMATA DI PREDAZIONE DI PESCE PORCO *OXYNOTUS CENTRINA* (LINNAEUS, 1758) SU CAPSULE OVARICHE DI GATTUCCI MINORI *SCYLIORHINUS CANICULA* (LINNAEUS, 1758) IN ACQUE MEDITERRANEE

SINTESI

L'esame del contenuto stomacale di due maschi di pesce porco Oxynotus centrina *(Linnaeus, 1758) catturati davanti al litorale di Barcellona nel novembre 2000 e nel gennaio 2001, ha rilevato la presenza di sacchi vitellini ed embrioni appartenenti alla specie dei gattucci minori* Scyliorhinus canicula *(Linnaeus, 1758). Per quanto è noto, si tratta della prima segnalazione confermata di predazione su capsule ovariche di gattucci minori in acque mediterranee.*

Parole chiave: *Oxynotus centrina, Scyliorhinus canicula,* predazione, capsula ovarica, embrioni, Mare Mediterraneo

INTRODUCTION

Records of predation on elasmobranch eggs are relatively rare (Cox & Koob, 1993). In this report we discuss the first confirmed record of elasmobranch predation on embryos of an oviparous shark in Mediterranean waters.

MATERIAL AND METHODS

Two angular roughshark *Oxynotus centrina* (Linnaeus, 1758) male individuals (Figs. 1, 2) were caught in Catalonia's continental slope waters on November 10th 2000 and January 2nd 2001 by the fishing vessel "Maireta II" based in the port of Barcelona (Spain). The specimens were caught using a trawler net at a depth of 192 m in the fishing ground know as "La Serola", at a geographical position of 41°12' N, 2°28' E (Fig 3). The specimens were identified according to Compagno (1984a). They were deposited at the Ichthyological Collection of the Zoology Museum of Barcelona, with catalogue numbers MZB-2000-1035 and MZB-2001-0006. The roughshark were examined for parasites. Stomachs were dissected and the contents identified. The reproductive tracts of individuals were examined to determine maturity in agreement with Moreno & Hoyos (1982).

RESULTS AND DISCUSSION

The two angular roughshark *O. centrina* male individuals measured both 555 mm total length. In table 1 the main morphometric data of specimens are presented following Compagno (1984a). Both were immature, and no internal or external parasites were found. The examination of one of the angular roughshark's stomach content revealed only fragments of ten yolk sacks and one 34 mm (total length) embryo (Fig. 4). The embryo, which had an external yolk sack, was determined to belong to the small-spotted catshark *Scyliorhinus canicula*, which was in agreement with the illustrations and morphological descriptions provided in Compagno (1984b), Moreno (1995) and Van Grevelynghe *et al.* (1999). The stomach content of the second shark showed two embryos at a total length of 60 mm from *Scyliorhinus canicula* (Fig. 5). No egg capsules were found. The egg content might have been sucked up by the angular roughshark.

Very little is known about the angular roughshark's diet. It is a solitary animal. However, two specimens are sometimes captured at the same time. Angular roughshark inhabits mud and sand-bottoms at depths of about 50-725 m (Barrull *et al.*, 1999) and it is thought that its diet consists of polychaetes and small animals from marine bottom (Compagno, 1984a; Barrull & Mate, 1996). Capapé (1975) points out that in Tunisian waters it feeds on crustaceans. Some species of carnivorous gastropods may drill into and feed on embryos, or developing its own young, in egg cases of some oviparous sharks (Mc Laughlin & O'Gower, 1971; Cox & Koob, 1993). Shark egg cases have been taken from stomachs of teleost (Long, 1996), marine mammals (Morejohn & Baltz, 1970; Jones, 1981; Condit & Le Boeuf, 1984; Antonelis *et al.*, 1987; Sinclair, 1994) and at least one species of shark (Grover, 1972). The fact that this is the first confirmed record of elasmobranches predation on shark eggs in Mediterranean waters provokes a special interest. Firstly because it reveals something new about

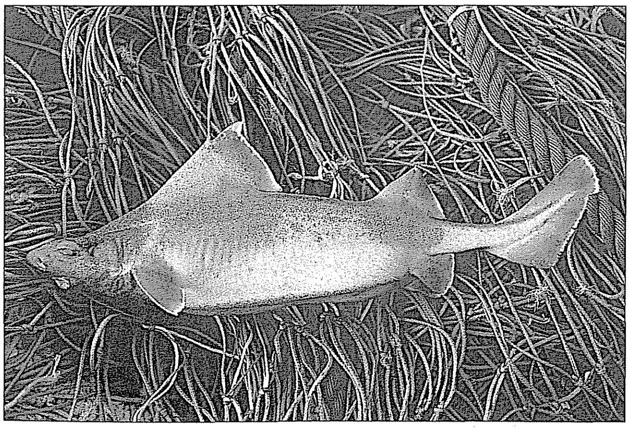

Fig. 1: Angular roughshark** Oxynotus centrina **caught on November 10th 2000 in coastal waters off Barcelona. (Photo: J. Barrull & I. Mate)

Sl. 1: Morski prašič** Oxynotus centrina, **ujet 10. novembra 2000 nedaleč od Barcelone. (Foto: J. Barrull & I. Mate)

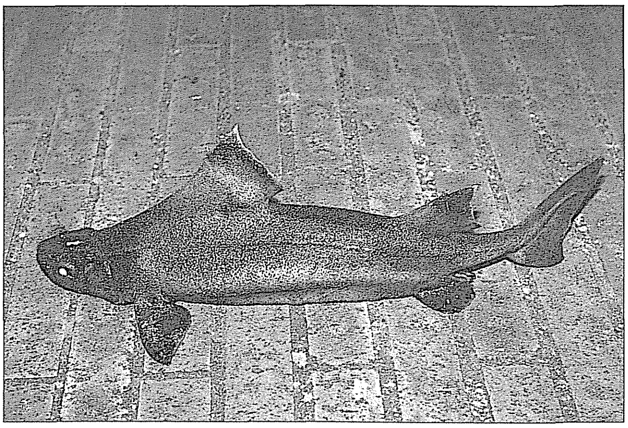

Fig. 2: Angular roughshark** Oxynotus centrina **caught on January 2nd 2001 in coastal waters off Barcelona. (Photo: J. Barrull & I. Mate)

Sl. 2: Morski prašič** Oxynotus centrina, **ujet 2. januarja 2001 nedaleč od Barcelone. (Foto: J. Barrull & I. Mate)

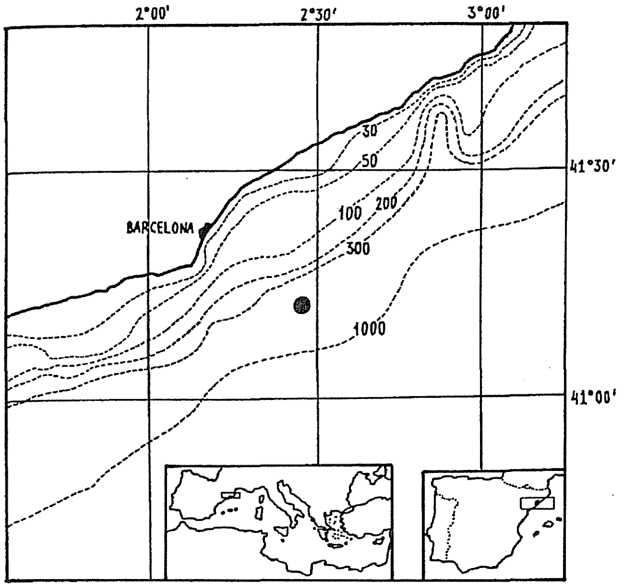

Fig. 3: Localization of the specimens of Angular roughshark** Oxynotus centrina **in the Barcelona littoral (NW Mediterranean).
Sl. 3: Lokacija osebkov morskega prašiča** Oxynotus centrina **v barcelonskem obrežnem pasu (SZ Sredozemsko morje).

angular roughshark's diet, and secondly for the consequences that this predation may have on species whose eggs are eaten.

The records of shark egg cases in stomachs of marine animals are rare (Cox & Koob, 1993). The question is how often this predation occurs. Small-spotted catshark eggs can be an important nutritional source, due to their high fat and protein content, and their accessibility. It is also important to point out that small-spotted catsharks and angular roughsharks have a similar bathymetrical distribution in almost all the continental slope and at different depths (Barrull *et al.*, 1999). So, this kind of interaction would not be surprising.

It would be worth finding out how this predation could affect the small-spotted catshark population. Angular roughsharks are considered an unusual and not a very prolific shark, due to their year-long reproductive period, with litters between 8 and 23 young (Capapé *et al.*, 1999, 2000), while the small spotted cat shark is considered an abundant and very prolific species. Also with a year reproductive period (with seasonal fluctuations), can produce between 96-115 egg cases each year (Capapé, 1977). Considering all these facts, we assume that angular roughshark's predation on the small-spotted catshark's eggs will not threaten its population. It would be necessary, however, to acquire more documentation to adequately analyse this phenomena.

The fact that this may be the first accurately documented instance of elasmobranch predation on embryos of an oviparous shark in Mediterranean waters, should warrant the special interest.

ACKNOWLEDGEMENTS

We wish to thank Mr. David Albiol for his help in collecting sharks, and Dr. Domènech Lloris for his helpful comments on the manuscript. We also would like to thank Ingrid Benito for translating the article into English, and Tiziano Storai for translating the abstract into Italian.

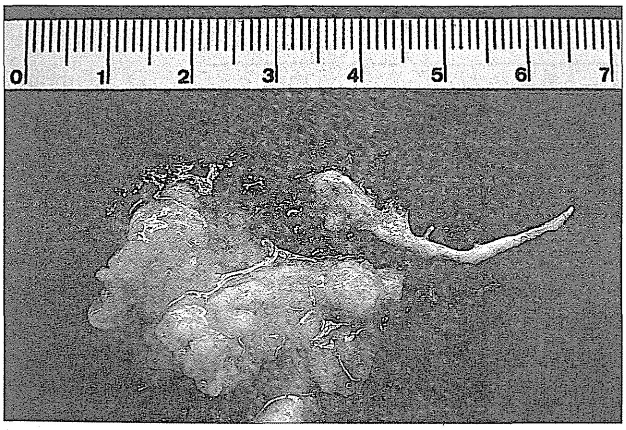

Fig. 4: Fragments of yolk sacks and 34 mm small-spotted catshark embryo from the stomach content of the November specimen. (Photo: J. Barrull & I. Mate)
Sl. 4: Delci rumenjakovih vrečk in 34 mm dolgega zarodka morske mačke iz želodca v novembru ujetega morskega prašiča. (Foto: J. Barrull & I. Mate)

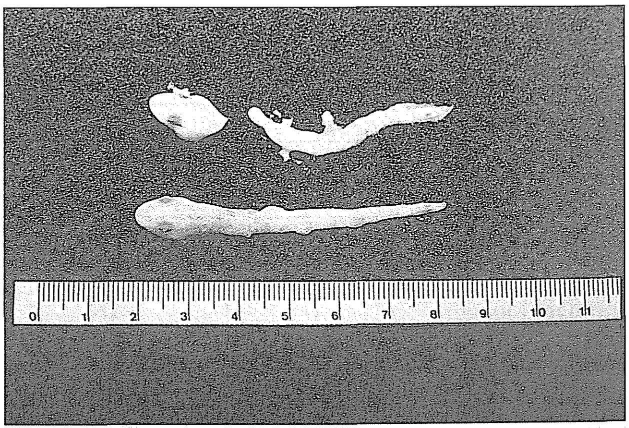

Fig. 5: 60 mm small-spotted catshark embryos from the stomach content of the January specimen. (Photo: J. Barrull & I. Mate)
Sl. 5: 60 mm dolgi zarodki morske mačke iz želodca v januarju ujetega morskega prašiča. (Foto: J. Barrull & I. Mate)

***Tab. 1:* Proportional dimensions of the two angular roughsharks caught off Barcelona.**
***Tab. 1:* Proporcionalne dimenzije dveh morskih prašičev, ujetih v obrežnih vodah Barcelone.**

		MZB-2000-1035	MZB-2001-0006
		Sex (M)	*Sex (M)*
total length (mm)	**TL**	555	555
precaudal length	**PRC**	79.8	80.2
pre-first dorsal length	**PD1**	19.4	19.1
pre-second dorsal length	**PD2**	58.4	57.9
first dorsal length	**D1L**	25.2	22.9
second dorsal length	**D2L**	14.8	14.9
first dorsal base	**D1B**	20.9	18.9
second dorsal base	**D2B**	11.7	10.4
first dorsal inner margin	**D1I**	4.3	4.0
second dorsal inner margin	**D2I**	3.1	4.5
first dorsal height	**D1H**	12.1	12.6
second dorsal height	**D2H**	10.3	10.6
first spine length	**S1**	11.0	13.1
second spine length	**S2**	8.8	7.4
dorsal caudal margin	**CDM**	20.7	20.4
preventral caudal margin	**CPV**	12.1	11.3
terminal caudal lobe	**CTL**	6.5	6.7
prepectoral length	**PP1**	18.6	18.5
pectoral anterior margin	**P1A**	15.5	16.0
pectoral posterior margin	**P1P**	14.4	14.0
pectoral base	**P1B**	5.8	4.9
pectoral inner margin	**P1I**	2.5	4.5
prepelvic length	**PP2**	62.2	60.9
pelvic length	**P2L**	10.1	10.8
pelvic anterior margin	**P2A**	6.7	6.1
clasper outer length	**CLO**	1.1	1.3
clasper inner length	**CLI**	5.9	6.1
mouth width	**MOW**	4.6	4.2
preoral length	**POR**	4.0	5.4
nostril width	**NOW**	2.2	3.4
internarial space	**INW**	1.1	2.5
prenarial length	**PRN**	2.0	3.6
prespiracular length	**PSP**	9.4	9.9
preorbital length	**POB**	4.3	7.7
eye length	**EYL**	4.3	3.8
eye height	**EYH**	2.1	2.0
intergill length	**ING**	4.0	5.1
first gill slit height	**GS1**	1.3	1.7
fifth gill slit height	**GS5**	1.5	1.5

PRVI POTRJENI PRIMER OPLENJENEGA JAJČNEGA OVOJA MORSKE MAČKE *SCYLIORHINUS CANICULA* V TREBUHU MORSKEGA PRAŠIČA *OXYNOTUS CENTRINA* (LINNAEUS, 1758) V SREDOZEMSKEM MORJU

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POVZETEK

Podatki o plenjenju jajčec morskih psov in skatov so razmeroma redki. Nekatere vrste mesojedih polžev lahko vrtajo v zarodke (in se hranijo z njimi) ali vzrejajo zarod v kapsulah oviparnih morskih psov. Jajčni ovoji sami pa so bili najdeni v želodcih pravih kostnic, morskih sesalcev in v najmanj eni vrsti živorodnega morskega psa. V tem prispevku avtorja razpravljata o bržkone prvem potrjenem primeru plenjenja zarodkov oviparnega morskega psa v vodah Sredozemskega morja. Dne 10. novembra 2000 in 2. januarja 2001 sta bila z vlečno mrežo ribiške ladje "Maireta II" (z matičnim pristaniščem v Barceloni) ujeta dva 550 mm dolga samca morskega prašiča Oxynotus centrina *(Linnaeus, 1758) v vodah celinskega pobočja nedaleč od katalonskega obrežja. Ujeta sta bila v globini 192 metrov na ribiški lokaciji, znani kot "La Serola", in sicer 41°12' N, 2°28' E. Oba samca sta bila izročena Zoološkemu muzeju v Barceloni in označena s kataloškima številkama MZB-2000-1035 in MZB-2001-0006. Pregled želodca enega od morskih prašičev je razkril delce desetih rumenjakovih vrečk in enega zarodka v skupni dolžini 34 mm. Na osnovi primerjav z ilustracijami in morfološkimi opisi Compagna (1984a), Morena (1995) in Van Grevelyngheja* et al. *(1999) je bilo ugotovljeno, da je zarodek, z zunanjo rumenjakovo vrečko, pripadal morski mački* Scyliorhinus canicula *(Linnaeus, 1758). V želodcu drugega morskega prašiča pa sta bila odkrita dva zarodka morske mačke* Scyliorhinus canicula *v skupni dolžini 60 mm. Jajčnih ovojev ni bilo, in prav mogoče je, da je morski prašič jajčno vsebino izsesal.*

Ta primer bo bržkone pritegnil še nadaljnje zanimanje strokovnjakov, saj je prvi natančno dokumentirani zapis o morskih psih (Elasmobranchii) z uplenjenimi zarodki oviparnega morskega psa v vodah Sredozemskega morja.

Ključne besede: *Oxynotus centrina, Scyliorhinus canicula,* predatorstvo, jajčni ovoj, zarodki, Sredozemsko morje

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MARBLE TROUT *(SALMO MARMORATUS)* AND BULLHEAD *(COTTUS GOBIO)* IN TWO SLOVENE RIVERS (ADRIATIC SEA BASIN)

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ABSTRACT

Population density, growth and condition of marble trout Salmo marmoratus *Cuvier, 1829 in the river Trebuščica and bullhead* Cottus gobio *Linnaeus, 1758 in the river Bela were estimated. Ageing of bullhead could not be established due to its lack of scales. In the Trebuščica, marble trout is a dominant species, with high density of 955 specimens/ha and low biomass of 26 kg/ha. The youngest marble trout specimens (age groups 0 and 1) constitute 81% of the entire estimated population. The mean condition factor was low (0.83) with the highest growth rate of 6-15 cm long trout (1.56 and 0.86, respectively). For the conservation of this species, no further introduction of brown and rainbow trout is recommended and angling restrictions of marble trout applies. In the river Bela, about 86% (specimens/ha) and 35% (kg/ha) of the total fish population are represented by bullheads. Bullheads' density of 11,708 specimens/ha is the first record of such high density in Slovenia. The mean condition factor of bullhead was rather high (1.01).*

Key words: marble trout, bullhead, population density, age, growth, condition, Slovenia

TROTA MARMORATA *(SALMO MARMORATUS)* E SCAZZONE *(COTTUS GOBIO)* IN DUE FIUMI IN SLOVENIA (BACINO ADRIATICO)

SINTESI

L'articolo riporta i dati inerenti la densità di popolazione, la crescita e la condizione della trota marmorata (Salmo marmoratus *Cuvier, 1829) nel fiume Trebuščica e dello scazzone* (Cottus gobio *Linnaeus, 1758) nel fiume Bela. Per la trota marmorata sono state studiate anche le classi d'età. La trota marmorata è la specie dominante nel Trebuščica, con una densità molto alta pari a 955 individui per ha ed un basso valore di biomassa, 26 kg per ha. Gli individui più giovani di questa specie (classi d'età 0 e 1) rappresentano l'81% dell'intera popolazione stimata. L'indice di condizione medio è risultato basso, pari allo 0.83, con il più alto tasso di crescita delle trote di 6-15 cm (rispettivamente 1.56 e 0.86). Per la tutela di questa specie, gli autori raccomandano di evitare ulteriori introduzioni di esemplari di trota fario e trota iridea, nonché di applicare restrizioni alla pesca della trota marmorata. Nel fiume Bela lo scazzone rappresenta l'86% (esemplari per ha) ed il 35% (kg per ha) dell'intera popolazione ittica. La densità dello scazzone, pari a 11708 individui per ha, corrisponde alla densità più alta mai segnalata in Slovenia.*

Parole chiave: trota marmorata, scazzone, densità di popolazione, età, crescita, condizione, Slovenia

INTRODUCTION

The marble trout (*Salmo marmoratus* Cuvier, 1829) is the second largest European, exclusively freshwater salmonid species. It inhabits fast running streams with gravel bottom, low summer water temperature and high dissolved oxygen content. Marble trout is endemic to the Adriatic Sea basin, listed in Annex II at "Council on the Conservation of Natural Habitats and of Wild Fauna and Flora" (Council Directive 92/43/EEC). In the Red Data List of the freshwater fish and lampreys of Slovenia (Povž, 1996), the species is listed as endangered and it is protected by the National and Regional laws. The marble trout has restricted geographical distribution in the basin of the Po in northern Italy and in the Adriatic basins of the former Yugoslavia and Albania (Crivelli *et al.*, 2000).

The bullhead *(Cottus gobio* Linnaeus, 1758*)* is a small benthic fish living in clear and well-oxygenated waters, inside the salmonid zone. Bullhead, too, is threatened by water pollution and stream regulation, and the species is listed in the Slovenian Red Data List (Povž, 1996) as vulnerable. It has been protected by the "Decree of Protection of Endangered Animal Species" (Official Journal R Slovenia No. 57/1993).

Data presented in this paper are part of a complex ichthyological investigation, commissioned and financed by the manager of the freshwater fish populations in these rivers - the Fishery Society of Tolmin. The aim of this investigation was to asses, on the basis of certain physical, chemical and biological features, the ecological condition of the streams and to implement the proposals for further fishery management. The fieldwork was conducted in September 1998 and March 1999, but due to the prolonged rainy period and devastating floods in November 1998, only the 1998 data are presented herewith. This work was read at the "International Symposium on Freshwater Fish Conservation: Options for the Future" held in Albufeira in Portugal (Šumer *et al.*, 2000).

Data presented in this paper are the very first on the marble trout and bullhead populations concerning the Bela and Trebuščica rivers. The condition factors of both species and instantaneous growth rates for marble trout have never been calculated before in this country.

MATERIAL AND METHODS

Study area

The river Bela is a north-western tributary of the river Nadiža. Only part of the Nadiža, with its source in Italy, flows along the Slovenian border area and joins the river Ter in Italy. The Bela, with its source at 1,140 m a.s.l., is only 6.29 km long and flows into the Nadiža at an altitude of about 300 m a.s.l. (Fig. 1). Unfortunately, there are no data available on the drainage area, river hydrology, or water quality.

The Bela was regulated in 1930. Its upper course has few 1-2 m high artificial weirs. This part is the trout's nursery stream. In its lower 4 km long course angling is practised. The investigation was carried out on the site located about 1 km upstream of the Bela's mouth. The 70 m long net–blocked segment (471 m^2) was selected to cover potential habitat types available to the dealt with fish species.

The river Trebuščica is a 16.4 km long south-western tributary of the Idrijca. Its source is at 1,125 m a.s.l. and joins the Idrijca at about 183 m a.s.l. (Fig. 1). Its catchment area covers 74 km^2. According to the Hydrometeorological Institute of Slovenia (1999 and 2000), the annual water level fluctuated from 0.45 - 0.63 m to the highest 3.27 m. Annual water discharge varied from 0.5 m^3/s to 2.7 m^3/s with the maximum of 58.7 m^3/s. The upper 6 km of the Trebuščica is a sanctuary area, inhabited by genetically pure marble trout, followed by 1 km of nursery stream. The lower 9.4 km long course is used for angling.

The investigation was carried out on the site some 3.5 km upstream of the mouth. The 150 m long net–blocked segment (2,136 m^2) was selected to cover potential habitat types available to the dealt with fish species.

Sampling and methods

Fish sampling was carried out on September 19, 1998. Fish were progressively captured and removed during three to four passes with DC electrofishing equipment until the last catch reached about 15% of the first catch. Sampled sections were blocked at the upper and lower ends with 6-mm seins. Captured fish were anaesthetised, identified, measured to the nearest mm (TL) and weighed to the nearest g. Ten to twenty scales were removed below the adipose fin and above the lateral line from each marble trout. Scales' annuli were examined at x 20-40 magnification, and annuli were identified following the criteria presented by Ricker (1968). The age of fish was presented as the age groups where age group 0 refers to the first year of life. Ageing of bullhead could not be estimated, as its body is not covered with scales.

The Zippin method (Higgins, 1985), where the numbers of fish in successive catches decrease ($n1>n2>n3$ etc.), and the Carle-Strub method, where $n1>n2<n3$ (Lobon-Cervia, 1984) were used to determine the fish density (specimens/ha) and biomass (kg/ha). Fulton's equation was used to calculate the condition factor $K = 100\ W/L^3$ (Velasco *et al.*, 1990), where L is total length (cm) and W is wet weight (g). Mean value of K for each age group was estimated separately. Instantaneous growth rates for each age group of marble trout G = Ln

(W_{t+1}/W_t), where W is mean weight, were also calculated (Velasco *et al.*, 1990).

Dissolved oxygen, pH, nitrate (NO_3^-), nitrite (NO_2^-), ammonia ion (NH_4^+), phosphate (PO_4^{3-}), total hardness, alkalinity, temperature, conductivity, current velocity, water discharged, and total dissolved solids (TDS) were measured. Using the transect system described by Platts *et al.* (1983), stream physical features were measured at each investigated site. Bottom substrate particle sizes were determined according to Allan (1995).

For water quality determination (Surber sampler), benthic macroinvertebrates were analysed using biotic index - I.B.G.N. (Compagnat *et al.*, 1994), and their biomass was estimated by using wet weight.

RESULTS AND DISCUSSION

The lower part of the river Bela

In view of its physical and chemical water characteristics, the Bela is a small and torrential river with diverse bottom stony substrate (Tab. 1). Thirty different macroinvertebrates taxa were found. Numerous small organisms were the main cause for its low estimated biomass of 11 kg/ha. Its water quality is 1st class (oligosaprobic). All determined chemical concentrations were bellow-regulated concentrations for unpolluted waters (Zupan *et al.*, 1996).

The Bela's lower course is inhabited by three salmonid species, one hybrid *(S. marmoratus* x *S. trutta* m. *fario)* and one species of the Cottidae family (Tab. 2).

C. gobio is a dominant species in the Bela, with 86% (specimens/ha) and 35% (kg ha) of the total estimated fish population size. Such high density of *C. gobio* has not been recorded in any Slovene water so far. At the same time we could confirm the high density of both hybrids and introduced rainbow trout *(Oncorhynchus mykiss)*. Between 45 and 67% of them were individuals of age groups 0 and 1. This is also the proof of a successful reproduction of the rainbow trout in the stream. The condition factors of these specimens were also high (0.95).

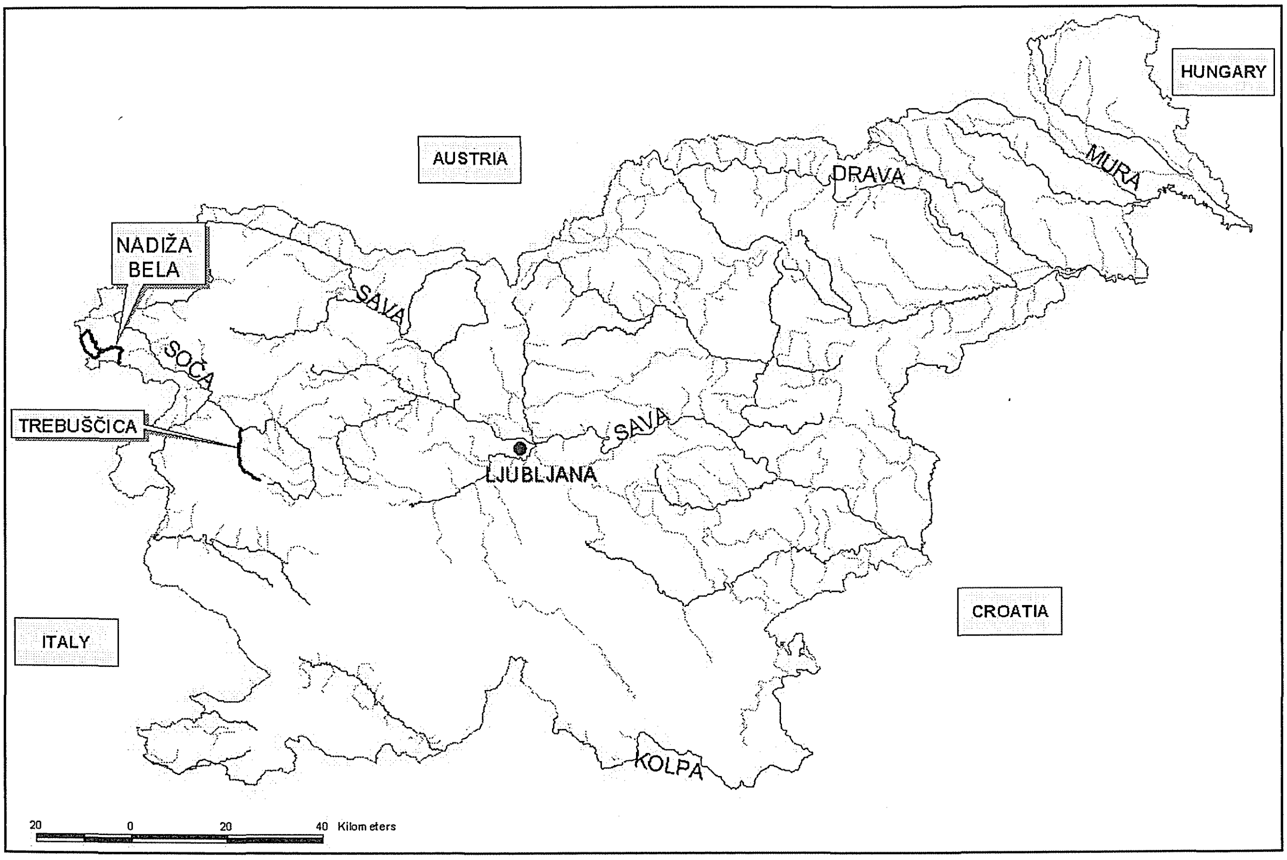

Fig. 1: Geographical location of the Bela and Trebuščica rivers in Slovenia.
Sl. 1: Geografska lega rek Bele in Trebuščice.

Tab. 1: Physical and chemical features of the Bela and Trebuščica rivers. Mean width (m) and depth (cm) with their range and bottom substrate particle sizes.

Tab. 1: Fizikalne in kemijske značilnosti rek Bele in Trebuščice. Povprečna širina (m) in globina (cm) obeh rek, razpon globine in širine ter velikost mineralnih delcev rečnega dna.

W (Min-Max)	D (Min-Max)	Bottom substrate (%)				O_2 (mg l^{-1})	TDS (mg l^{-1})	pH	T (°C)	Conduc. (μS cm^{-1})	Velocity (m s^{-1})	Discharge (m^3 s^{-1})	Hardness (°N)
		Boulders	Cobbles	Gravel	Sand								
RIVER BELA													
6.9 (5.8-10)	37.6 (25-54)	17.5	41.6	37.1	3.75	11	130	8.4	12.5	260	0.82	2.15	10.5
RIVER TREBUŠČICA													
11.11 (1.2-17.7)	32 (5-135)	0	30	63	7	11.4	130	8.7	10	280	0.61	1.6	11

Legend: W: mean width (m), D: mean depth (cm), Min-Max: minimum-maximum values, boulders >256 mm, cobbles: 64-256 mm, gravel: 2-64 mm, sand: 0.06-2 mm.

Legenda: W: povprečna širina (m), D: povprečna globina (cm), Min-Max: najnižje – najvišje vrednosti, veliki kamni >256 mm, večji prodniki: 64-256 mm, prod: 2-64 mm, pesek: 0,06-2 mm.

Tab. 2: Fish density (specimens/ha) and biomass (kg/ha) with ± 95% CI (± 95% Confidence interval) in the Bela and Trebuščica rivers.

Tab. 2: Gostota (število rib/ha) in biomasa (kg/ha) rib ± 95% CI (± 95% interval zaupanja) v Beli in Trebuščici.

	RIVER BELA		RIVER TREBUŠČICA	
Species	specimens/ha	kg/ha	specimens/ha	kg/ha
S. marmoratus	319 (± 8)	7.7 (±1.8)	**955 (±77)**	**25.6 (±1.9)**
S. t. m. *fario.*	43 (±0)	12 (±0)	75 (±0)	4.2 (±0)
S. t. m. *fario x S. marmoratus*	1,940 (±29)	127.8 (±2.9)	585 (±11.5)	18.9 (±0.4)
O. mykiss	1,241 (±33)	74.6 (±5)	252 (±24)	11.7 (±0.8)
Thymallus thymallus			24 (±5)	2.7 (±0.9)
Phoxinus phoxinus			30 (±8)	0.6 (±0)
Barbus caninus			20 (±8)	1.1 (±0)
C. gobio	**11,708 (±1,811)**	**75.2 (±0)**		
TOTAL	13,619 (±745)	212 (±26)	1,926 (±58)	64.4 (±2.6)

Tab. 3: Mean body length, weight, condition factor, and growth rate of Salmo marmoratus ***from the river Trebuščica and of*** Cottus gobio ***from the river Bela.***

Tab. 3: Povprečna telesna dolžina, teža, indeks kondicije in stopnja rasti soške postrvi Salmo marmoratus ***v reki Trebuščici in kaplja*** Cottus gobio ***v reki Beli.***

	River Trebuščica - *S. marmoratus*						River Bela - *C. gobio*
Parameters	Age group (years)						
	0	1	2	3	4	7	
n	59	91	24	2	7	1	400
L	8(±1.24)	13.3(±1.06)	17.4 (±1.48)	21.8 (±1.06)	28 (±0.58)	41	9.1 (±2.17)
L-range	6-11.5	11.5-15	15.5-19.8	21-22.5	27-28.5		4.5-13.5
W	4.3 (±2.43)	20.3 (±4.93)	47.8 (±13.12)	85 (±18.38)	189.4 (±15.95)	700	8.9 (±5.38)
W-range	1.8-14	10-32	30-70	72-98	160-206		0.8-24
K	0.78 (±0.15)	0.85 (±0.07)	0.89 (±0.07)	0.82 (±0.06)	0.86 (±0.04)	1.02	1.01 (±0.13)
K-range	0.78-1.1	0.66-1.04	0.76-0.99	0.78-0.86	0.81-0.92		0.58-1.27
G	-	1.56	0.86	-	-		

Legend: n = number of fish caught, L = mean total length (cm) ±SD (standard deviation), W = mean weight (g) ±SD, K = mean condition factor ±SD, G = instantaneous growth rate of weight.

Legenda: n = število ujetih rib, L = povprečna totalna dolžina (cm) ±SD (standardna deviacija), W = povprečna teža (g) ±SD, K = povprečni indeks kondicije ±SD, G = trenutna stopnja rasti v teži.

According to Gaudin & Caillere (1990), *C. gobio* prefers shallow waters and slow to moderate current velocities, shaded areas and scarce emergent vegetation. They cite the results of other authors according to whom, quite on the contrary, the species can be found also in the zones where velocity is high. Its presence is dependent on substrate, the granulometry characterized by enough coarse elements.

The low banks of the Bela offer no overhanging vegetation and therefore no shaded areas. The river bed microhabitats had patches of algae, and occasionally *Fontinalis* sp. appeared. The number of caught bullheads was nearly the same along the entire sampling location, regardless of riffles and pools. According to Gaudin & Caillere (1990), *C. gobio* is indifferent to water depth (up to 6-9 m) but prefers coarse bottom material that gives it shelter. The Bela bottom material consists of rubbles and boulders as the main fish cover areas.

The length of the specimens (Tab. 3) was inside the length intervals cited by Oliva *et al.* (1968), Ladiges & Vogt (1979) and Terofal (1996). The mean condition bullheads' factor was rather high 1.01. According to the high population density and the estimated condition factor it appears that the Bela holds favourable environmental conditions for this species.

The river Trebuščica

In general, the lower course of the Trebuščica is wider than the Bela, characterized by more fluctuating water depth and stream width and less diverse bottom substrate (Tab. 1). Twenty different macroinvertebrates taxa were identified. Their low biomass (6 kg/ha) is among the lowest benthic biomasses recorded in the streams of the Adriatic Sea basin (with regard to the September sampling). Its water quality is 2nd class (betamesosaprobic). Surrounding areas are free of industry, but with more inhabitants, villages and arable land. In the Trebuščica, too, all determined chemical concentrations were bellow regulated concentrations for unpolluted waters (Zupan *et al.*, 1996).

Six fish species and a hybrid *(S. marmoratus* x *S. trutta* m. *fario)* of the families Salmonidae, Cyprinidae and Thymallidae inhabit the Trebuščica. *S. marmoratus* makes 49% of the Trebuščica's total estimated population density and 40% of its total biomass. Its population density is among the highest in the Slovenian Adriatic Sea basin streams (Tab. 2).

The estimated biomass was low due to high abundance (81%) of young fish (age groups 0 and 1). There were only few sexually mature specimens of age groups 3 and 4. In comparison with other salmonids, the condition factor of the marble trout was the lowest, while the growth rate of 6-15 cm long specimens was the highest (Tab. 3). The reason for the lowest condition factor may be associated with limited environmental conditions and introduced indigenous fish species occupying available ecological niches in the stream.

The relatively high abundance of young fish is due to the fishery management. From 1996 on, marble trout of size 9-15 cm have been intensively stocked. At the same time there is also a possibility of migrations from the upper course of the river, inhabited only with marble trout (sanctuary and nursery stream segments). There are numerous young fish, with very few catchable size adults.

In Slovenia, strong decline of this species has been recorded during the last 80 years. It is threatened by a permanent introduction of brown trout *(Salmo trutta)*, water pollution, river regulation and reservoir constructions (Povž *et al.*, 1996). The marble trout is heavily affected by stocked alien Atlantic *S. trutta* and Danubian and/or Mediterranean *Salmo* species, and presently there are only few populations of marble trout that are believed to be unaffected by introgression (Delling *et al.*, 2000). By the end of the last century, brown trout of different origins have been introduced into geographical area where the marble trout occurs, quickly resulting in hybrid populations (Crivelli *et al.*, 2000). In the Adriatic basin of Slovenia, the first introductions took place in 1906 (Povž *et al.*, 1996). During the marble trout rehabilitation project, which began in 1993, eight genetically pure populations were discovered in headwater streams in the upper reaches of the Soča river in Slovenia, the Trebuščica being one of them. As a result of the first phase of this project, the prohibition on the release of *Salmo trutta* in the Soča watershed became effective in 1996 with the "Curricular for the ban of brown trout stocking in the Adriatic Sea basin, Slovenia" (Ministry of Agriculture, Forestry and Food, March 25th, 1996).

Both rivers are rather narrow with low water level (especially the Bela). According to the September data, the amount of food source is quite limited. The latter and the genetic conservation of marble trout were the most important reasons for the recommendation of a suitable management based on no introduction of other fish species and angling restrictions of marble trout.

SOŠKA POSTRV (*SALMO MARMORATUS*) IN KAPELJ (*COTTUS GOBIO*) V DVEH SLOVENSKIH REKAH SEVERNOJADRANSKEGA POVODJA

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POVZETEK

Avtorji pričujočega raziskovalnega dela so merili populacijsko gostoto, stopnjo rasti in kondicijsko stanje soške postrvi Salmo marmoratus *Cuvier, 1829 v reki Trebuščici ter kaplja* Cottus gobio *Linnaeus, 1758 v reki Beli. Starostno strukturo so ugotavljali le pri soški posrtvi. Soška postrv je v Trebuščici dominantna vrsta z visoko gostoto 955 osebkov/ha in nizko biomaso 26 kg/ha. Najmlajši osebki soške postrvi (starostna skupina med 0 in 1) sestavljajo 81% celotne ocenjene populacije. Povprečni indeks kondicije je bil nizek (0,83) z visoko stopnjo rasti 6-15 cm dolgih postrvi (1,56 oz. 0,86). Za zaščito avtohtone soške postrvi avtorji odsvetujejo nadaljnje vlaganje amerikank in potočnih postrvi in hkrati vztrajajo pri omejitvah športnega ulova soške postrvi. Kaplji v reki Beli sestavljajo kakih 86% (osebkov/ha) in 35% (kg/ha) celotne ribje populacije. Njihova gostota 11.708 osebkov/ha je najvišja, kar jih je bilo doslej zabeleženih v Sloveniji. Povprečni indeks kondicije kapljev je bil razmeroma visok (1,01).*

Ključne besede: soška postrv, kapelj, populacijska gostota, starost, stopnja rasti, kondicijsko stanje, Slovenija

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SOME NEW DATA ON *XYRICHTHYS NOVACULA* (LINNAEUS, 1758) AND *SPARISOMA (EUSCARUS) CRETENSE* (LINNAEUS, 1758) FROM THE EASTERN ADRIATIC

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ABSTRACT

A cleaver wrasse, Xyrichthys novacula, *and a parrotfish,* Sparisoma (Euscarus) cretense, *were caught near Jelsa (Hvar Island) and the Vrhovnjaci archipelago in September and October 2000, respectively. Two specimens of parrotfish were also recorded by visual census in the Palagruža archipelago. As far as the cleaver wrasse is concerned this is, to our best knowledge, the northernmost record of this particular species in the Adriatic Sea. The main morphometric and meristic data are given for both species. The presented morphometric and meristic data of* S. cretense *are the first for this species from the Adriatic Sea.*

Key words: *Xyrichthys novacula, Sparisoma (Euscarus) cretense,* Eastern Adriatic

NUOVI DATI SU *XYRICHTHYS NOVACULA* (LINNAEUS, 1758) E *SPARISOMA (EUSCARUS) CRETENSE* (LINNAEUS, 1758) NELL'ADRIATICO ORIENTALE

SINTESI

Xyrichthys novacula, *pesce pettine, e* Sparisoma (Euscarus) cretense, *pesce pappagallo, sono stati pescati nei pressi di Jelsa (isola di Hvar) e dell'arcipelago di Vrhovnjaci, rispettivamente in settembre e ottobre 2000. Due esemplari di pesce pappagallo, inoltre, sono stati avvistati con la tecnica del censimento visivo nell'arcipelago di Palagruža. In base alle pubblicazioni disponibili, il ritrovamento del pesce pettine corrisponde alla segnalazione più settentrionale di tale specie nel mare Adriatico. Nell'articolo vengono riportati i principali dati morfometrici e meristici per entrambe le specie. I dati riguardanti* S. cretense *sono i primi per questa specie nel mare Adriatico.*

Parole chiave: *Xyrichthys novacula, Sparisoma (Euscarus) cretense,* Adriatico orientale

INTRODUCTION

Some 411 fish species and subspecies (Cyclostomata not included) have been observed in the Adriatic Sea (Dulčić, 2000), and this number can so far be regarded as correct and complete for several reasons. Of this number, the very rare and rare fishes make up almost a quarter (96; 23.4%). Two species, cleaver wrasse *Xyrichthys novacula* (Linnaeus, 1758) and parrotfish *Sparisoma (Euscarus) cretense* (Linnaeus, 1758), belong to the very rare species in the Adriatic Sea (Pallaoro & Jardas, 1996).

The records on biology and ecology of these two species in the Adriatic Sea are scarce in literature. Some data existed on *X. novacula* (Onofri, 1977, 1982, 1987, 1997) and *S. cretense* (Morović, 1979), but most of them are of general character.

The main goal of this paper is to present some new data (morphometric and meristic characteristics, northernmost record) on these two species from the Adriatic Sea.

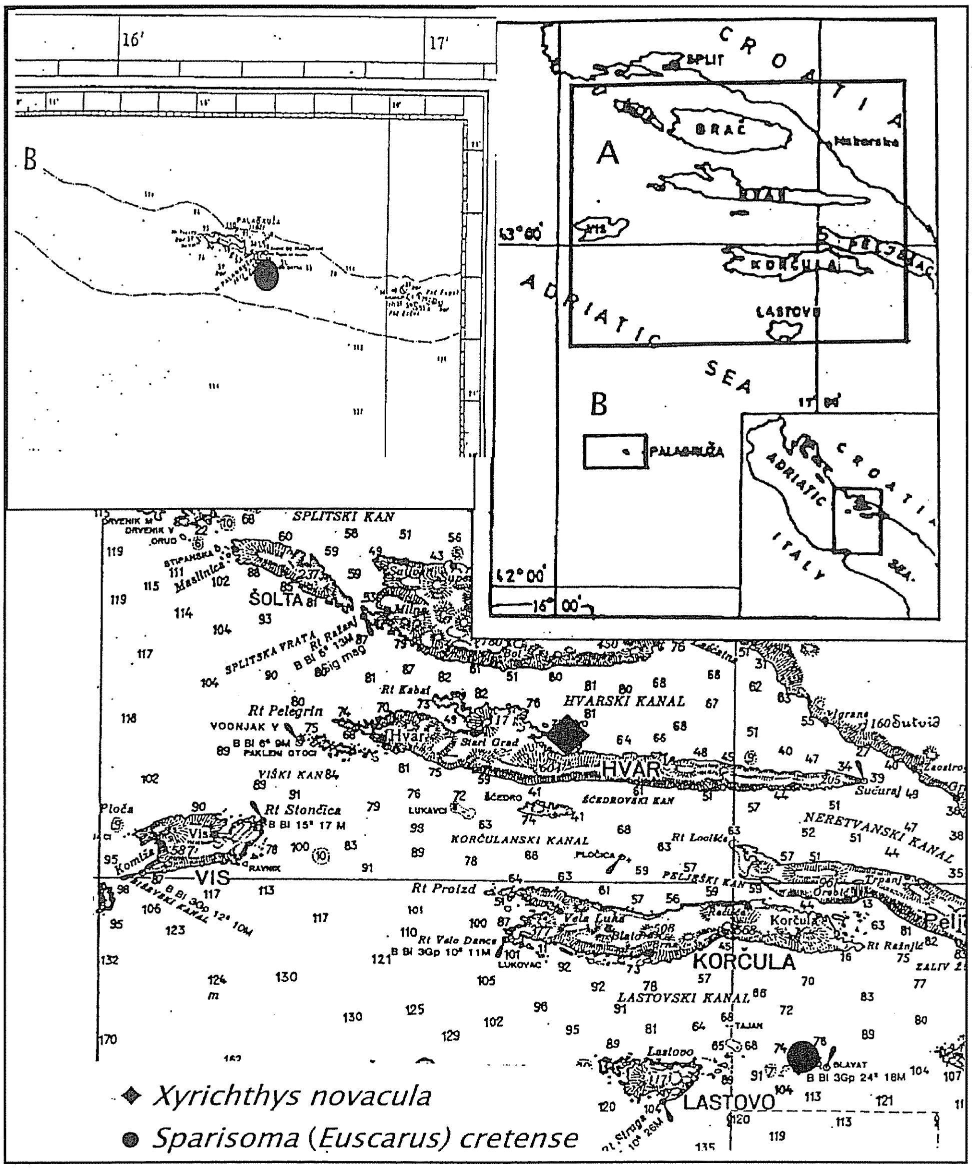

***Fig. 1: Geographic locations of** Xyrichthys novacula **and** Sparisoma cretense **records in the Eastern Adriatic: (A) Hvar Channel, near Jelsa, Vrhovnjaci archipelago; (B) Palagruža Island. Legend:** ◆ - Xyrichthys novacula, ● - Sparisoma cretense.*

***Sl. 1: Geografske lokacije pojavljanja vrst** Xyrichthys novacula **in** Sparisoma cretense **v vzhodnem Jadranu: (A) Hvarski kanal, bližina Jelse, otočje Vrhovnjaci; (B) otok Palagruža. Legenda:** ◆ - Xyrichthys novacula, ● - Sparisoma cretense.*

MATERIAL AND METHODS

The cleaver wrasse (female) (Fig. 2a) was caught (September 5th 2000) near Jelsa (the island of Hvar) (Fig. 1) at a depth between 10 and 15 m on sandy-muddy bottom (sea temperature was 22°C). The parrotfish (male) (Fig. 2b) was caught (October 2nd 2000) in the Vrhovnjaci archipelago (Fig. 1) at a depth between 4-5 m at the littoral bottom covered by photophile macroalgae (sea temperature was 21°C). Another parrotfish specimen (male) (Fig. 2c) was observed at the Palagruža Island (Fig. 1) in August 2000 by *visual census* (the divers were Tom Turk and Borut Furlan).

The specimens were identified according to Jardas (1996). They are deposited and registered (cleaver wrasse: 160A IOR; parrotfish: 161A IOR) in the Ichthyologic Collection of the Institute of Oceanography and Fisheries in Split, Croatia.

The specimens were preserved in 4% buffered formaldehyde immediately after capture, subsequently measured to the nearest 0.01 mm, and weighed to the nearest 0.01 g. Reduction in length caused by preservation depends on initial lengths of the specimens and duration of storage. Meristic characteristics considered were dorsal, anal, pectoral, ventral, caudal fins, and the number of scales in longitudinal line.

RESULTS AND DISCUSSION

In table 1, the main morphometric and meristic data of both species *X. novacula* and *S. cretense* are presented. The presented morphometric and meristic data of *S. cretense* are the first for this species from the Adriatic Sea and in agreement with those presented by Jardas (1996). Morović (1979) reported the length of 41 cm of the caught parrotfish specimen along the western coast of Biševo Island (Central Adriatic) (on 6 July 1962) and this has been, until now, the only reported length of this species caught in the Eastern Adriatic. The meristic and morphometric characteristics of the cleaver wrasse differ from the data by Quignard (1966) and Bini (1968), but are in agreement with those by Onofri (1977, 1982, 1987). Considering the meristic and morphological characteristics, a special cleaver wrasse variation for the Adriatic is possible (Onofri, 1982). A specimen of this species had two horns on the upper side of the head and this was the first record of such a form ever to be reported in the world ichthyologic literature (Onofri, 1987).

The record of the cleaver wrasse near Jelsa (Hvar Island) is, to our best knowledge, the northernmost record of this species in the Adriatic Sea. The cleaver wrasse is a species distributed in the Mediterranean and western Atlantic and generally found on shallow sand (Tortonese, 1975). Stossich (1880) was the first to report on the presence of this very rare species in the Adriatic but without the data about the sampling area. Onofri (1977, 1982) supposed that Stossich had treated it as a member of the fauna of the Gulf of Trieste. It has been proved that cleaver wrasse is present only in the Southern Adriatic on sandy bottom where the *Posidonia oceanica* and *Zostera marina* biocenosis are well developed (Onofri, 1977, 1978, 1982). All previous records of this species in the Adriatic have been made in the Pelješac Channel (Southern Adriatic) at depths around 15 m (Onofri, 1982, 1987, 1997) (Tab. 2).

Tab. 1:** **Morphometric (in mm) and meristic data of the cleaver wrasse and parrotfish in the Eastern Adriatic
Tab. 1:** **Morfometrični (v mm) in meristični podatki za ustnačo** Xyrichthys novacula **in papagajevko** Sparisoma cretense **v vzhodnem Jadranu

Species	*Xyrichthys novacula* (♀)	*Sparisoma cretense* (♂)
Weight (W) (in g)	85.47	238.76
Morphometric characters		
Total length (Lt)	18.53	25.33
Standard length (Ls)	16.02	22.16
Head length (Lc)	4.41	5.71
Predorsal length (Lpd)	3.09	6.18
Preanal length (Lpa)	7.47	12.82
Prepectoral length (Lpp)	4.05	5.56
Preventral length (Lpv)	4.02	6.35
Base length D (Ld)	10.44	11.58
Base length A (La)	6.52	4.87
Pectoral length (Lp)	3.32	4.47
Ventral length (Lv)	2.55	3.61
Caudal length (Lc)	3.04	4.96
Max. body height (Tmax)	5.35	6.77
Min. body height (Tmin)	2.07	2.68
Eye diameter (O)	0.71	1.02
Interorbital length (Io)	0.72	1.49
Preorbital length (Po)	1.80	2.03
Postorbital length (Olo)	1.90	2.66
Meristic characters		
Dorsal fin (D)	IX+12	IX+9
Anal fin (A)	III+12	III+9
Ventral fins (V)	I+5	I+5
Pectoral fins (P)	12	12
Caudal fin (C)	IV+12+IV	IV+12+IV
Linea lateralis (Ll)	27	23

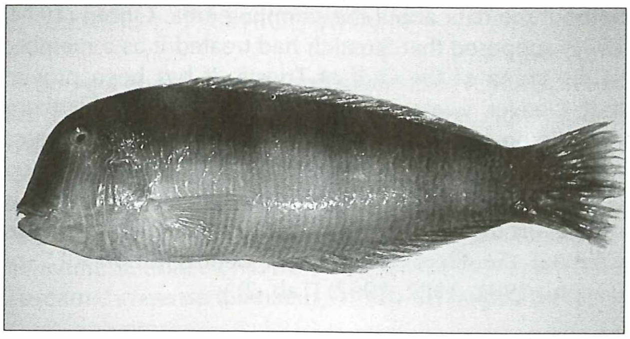

Fig. 2a: *Xyrichthys novacula,* **♀, 18.5 cm (Photo: J. Dulčić & A. Pallaoro)**
Sl. 2a: *Xyrichthys novacula,* **♀, 18,5 cm. (Foto: J. Dulčić & A. Pallaoro)**

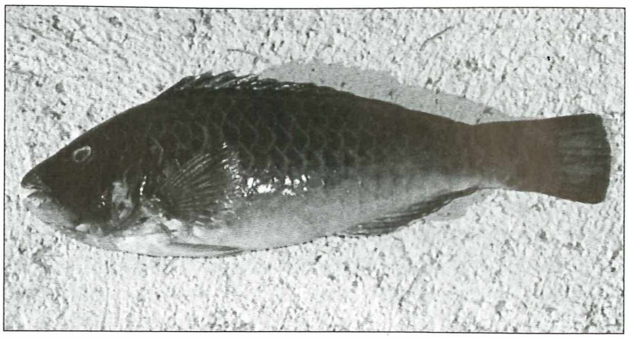

Fig. 2b: *Sparisoma cretense,* **♂, 25.3 cm, specimen caught near Jelsa, island Hvar. (Photo: J. Dulčić & A. Pallaoro)**
Sl. 2b: *Sparisoma cretense,* **♂, 25,3 cm, osebek ujet v bližini Jelse, otok Hvar. (Foto: J. Dulčić & A. Pallaoro)**

Fig. 2c: *Sparisoma cretense,* ***males observed by*** *visual census* ***at Palagruža Island. (Photo: B. Furlan)***
Sl. 2c: *Sparisoma cretense,* ***samec, opažen med potapljanjem ob otoku Palagruža. (Foto: B. Furlan)***

S. cretense was found in the sea from the northern to the southern part of the Adriatic (Tab. 2), although it clearly prefers its southern part (Jardas, 1996). Kolombatović (1900, 1904) reported how the first specimen caught in the Adriatic Sea was found at the fish market in Dubrovnik (Southern Adriatic); it was described by Baldo Kosić (famous ichthyologist at that time). The same author reported on two specimens, caught by Grgur Bučić (famous naturalist and meteorologist of that time) near the town of Hvar in 1903 (Tab. 2).

Tab. 2: Records of cleaver wrasse and parrotfish in the Eastern Adriatic.
Tab. 2: Podatki o pojavljanju ustnače *Xyricythys novacula* ***in papagajevke*** *Sparisoma cretense* ***v vzhodnem Jadranu.***

Species	Area/Date/Number	Source
Xyrichthys novacula	First record, Gulf of Trieste (??)	Stossich (1880)
	Pelješac Channel, western coast of the town of Korčula, 27.08.1977, one specimen (♀)	Onofri (1977)
	Pelješac Channel, western coast of the town of Korčula, several days after 27.08.1977, three specimens (♀)	Onofri (1982)
	Pelješac Channel, western coast of the town of Korčula, 1983, several specimens	Onofri (1997)
	Isle of Knežić, Lumbarda, Korčula Island, Pelješac Channel, 1988, one specimen	Pallaoro & Jardas (1996)
Sparisoma cretense	First record, Dubrovnik	Kolombatović (1900, 1904)
	The town of Hvar, Hvar Island, 1903, two specimens	Kolombatović (1900, 1904)
	Venice (Italy), one specimen	Ninni (1924), Bini (1968)
	Komiža, Vis Island, 07.08.1925, two specimens	Pallaoro & Jardas (1996)
	Biševo Island, 06.07.1962, one specimen	Morović (1979)
	Šćedro Island, 18.08.1965, one specimen	Morović (1979)

In the Mediterranean Sea, *S. cretense* is commonly distributed in the Eastern Basin and along the Northern African coasts (Bini, 1968; Papaconstantinou, 1992), whereas in the Western Basin it was only recorded off Marseilles, Nice, Valencia (Lozano Rey, 1952) and Balearic Islands (Riera *et al.*, 1995). The parrotfish is quite common along the southern coasts of Italy (Tortonese, 1975), conversely few records were collected along the northern ones. Bini (1968) reports the catch of a single specimen in the waters of Venice (Northern Adriatic Sea), while Bianchi and Morri (1994) recently pointed out its occurrence along the island of Giglio (Northern Tyrrhenian). The species is also found in the waters from Portugal and the Azores southwards to Senegal (Quignard & Pras, 1986). *S. cretense* reaches a maximum total length (TL) of 50 cm (commonly from 10 to 30 cm TL) and shows a marked sexual dichromatism. Two males from Palagruža and one from the Vrhovnjaci archipelago were found on rocky substrates with photophile macroalgae characterised by medium rigidity and gentle slope. Rocky and sandy bottoms with seagrass patches are the preferred habitats of this species (Tortonese, 1975; Jardas, 1996). The parrotfish was mostly observed at relative shallow stands, lower than 12 m depth, except for one small-sized specimen, with a peculiar livery, recorded on *Posidonia oceanica*. Therefore, this species seemed to prefer shallow rocky substrates with photophile macroalgae, as observed in this study and along the coast of Ustica Island (Vacchi *et al.*, 1999). Other authors (Bini, 1968; Tortonese, 1975) also reported on the occurrence of this species on soft bottoms.

The occurrence of *S. cretense* along Ustica Island (36 nautical miles off the northern coast of Sicily) is consistent with the northern extension of the biogeographical range of these thermophilous species, as a result of a warming up of the Mediterranean waters (see Francour *et al.*, 1994; Riera *et al.*, 1995). In particular, the capture of *S. cretense* in the Southern and Central Adriatic during this year occurred more and more frequently, suggesting an increase in the population density, which has been confirmed by the findings of relatively large number of specimens (by *visual census)* around the islands of Korčula (southern coast) and Mljet (southern coast) (Mušin, Onofri & Milišić, *pers. comm.)*. The northernmost record of the cleaver wrasse could also support the statement about the southern thermophilous species moving northwards in the last decade in the Adriatic Sea, which could be related to the changes in climate and/or oceanographical conditions (Dulčić *et al.*, 1999). The status of the cleaver wrasse and parrotfish needs to be evaluated on a continuous basis as it is becoming increasingly apparent that uncommon species, and particularly those on the edge of their distribution, can be essential indicators of environmental changes (Swabby & Potts, 1990).

NEKAJ NOVIH PODATKOV O VRSTAH *XYRICHTHYS NOVACULA* (LINNAEUS, 1758) IN *SPARISOMA (EUSCARUS) CRETENSE* IZ VZHODNEGA JADRANA

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POVZETEK

Septembra leta 2000 je bila v bližini Jelse (otok Hvar) ujeta samica ustnače Xyrichthys novacula, *oktobra istega leta pa na območju otočja Vrhovnjaci samec papagajevke* Sparisoma (Euscarus) cretense. *Dva samca papagajevke sta bila opažena tudi med potapljanjem na območju otoka Palagruže avgusta meseca istega leta. Pojavljanje ustnače* Xyrichthys novacula *je po najinih podatkih najsevernejše za to vrsto v Jadranu. V članku so podani vsi glavni morfometrični in meristični podatki za obe vrsti, ki so v primeru papagajevke hkrati tudi prvi podatki za Jadran nasploh. Odkritja papagajevke in ustnače severneje od območja, kjer je bila ta vrsta zabeležena do zdaj, bi zaradi dejstva, da sta obe vrsti v Jadranu redki in toploljubni, lahko povezali s spremembami v oceanografskih značilnostih Jadrana.*

Ključne besede: *Xriychthys novacula, Sparisoma* (*Euscarus*) *cretense*, vzhodni Jadran

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QUANTIFICATION OF MUCILAGE-ASSOCIATED SUSPENDED MATTER IN THE GULF OF TRIESTE (ADRIATIC SEA)

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ABSTRACT

Mucilage-associated suspended matter in the Gulf of Trieste has been quantified using different approaches during the 2000 event. Remote sensing, video recording and image analysis were used to assess the quantity of surfaced mucilage. The quantity of water column mucilage was estimated taking quantitative samples of mucilage using a peristaltic pump and using in situ *photography, video recording and image analysis. Samples of surface and water column mucilage were assessed for wet mass immediately after sampling, while for further analyses they were deep-frozen and analysed later. Our results indicate that during culmination of the 2000 event on average less than 2% of sea surface was covered by mucilage in offshore areas. The quantity of particulate matter in offshore surface mucilage was on average 220 mg carbon/L, however, mucilage was limited to less than 0.5 cm thick surface layer. Concentrations were significantly lower for the water column mucilage (47.6±1.7 mg C/L for mucilage clouds, 5.9±4.2 mg C/L for mucilage network). Integrating obtained values for the water column to a depth of 25 m we estimated the average quantity of mucilage-associated particulate matter in mid-June to be about 80 g C/m^2.*

Key words: mucilage, Adriatic Sea, quantification, video recording, remote sensing, image analysis, particulate matter accumulation

QUANTIFICAZIONE DELLA MATERIA SOSPESA ASSOCIATA ALLE MUCILLAGINI NEL GOLFO DI TRIESTE (MARE ADRIATICO)

SINTESI

Durante il manifestarsi delle mucillagini nell'anno 2000, con diversi approcci gli autori hanno quantificato la materia sospesa associata al fenomeno. A tale scopo sono state utilizzate immagini telerilevate da elicottero successivamente elaborate con programmi grafici (Adobe Photoshop, CorelPhoto-Paint) e con il programma per l'analisi di immagini satellitari ENVI. I campioni per l'analisi quantitativa delle mucillagini nella colonna d'acqua sono stati raccolti con l'aiuto di una pompa peristaltica. La quantità di mucillagini è stata calcolata come massa umida, sostanza secca e carbonio. I risultati dimostrano che durante la comparsa del fenomeno nel giugno 2000, in media meno del 2% della superficie marina è rimasta coperta dalle mucillagini. Nella colonna d'acqua la rete mucosa ha avuto un contenuto medio di 5.9±4.2 mg C/L, mentre le nubi mucose di 47.6±1.7 mg C/L. Gli autori hanno inoltre calcolato che nella colonna d'acqua di 25 metri la quantità di carbonio ha raggiunto, all'apice del fenomeno nel giugno 2000, valori medi di 80 g C/m^2.

Parole chiave: mucillagini, mare Adriatico, quantificazione, remote sensing, elaborazione di immagini, accumulo di materia sospesa

INTRODUCTION

Recent events (1988, 1989, 1991, 1997, 2000) of massive mucilage accumulation in the northern Adriatic have inflicted acute changes on the ecological dynamics of this marine system and have created serious problems for different human activities in the region. Due to the frequency of occurrence, geographical scale, subsequent ecological and socio-economic impacts as well as their intricacy, mucilage events have become a matter of high environmental concern. All this has prompted extensive research in the last decade and mucilage has become one of the priorities of the national marine research programmes of the Adriatic countries as well as that of major EU funded projects (Hopkins *et al.*, 1999). Numerous scientific papers have been published and up-to date knowledge has been synthesised in special volumes of scientific journals (Vollenweider *et al.*, 1995; Funari *et al.*, 2000). Yet, many aspects of this peculiar phenomenon, which in its extensiveness seems to be unique to the northern Adriatic, have remained unresolved.

Many researchers consider massive accumulations of mucilage as an extreme case of particulate matter aggregation. Aggregates are ubiquitous in marine and limnetic environments and are formed mainly from smaller particles in the water column. Coagulation is an important mechanism controlling aggregate size distribution. However, other features are also considered to be important in large aggregate formation such as abundance of TEP (transparent exopolymer particle) (Alldredge *et. al.*, 1993), presence of particular phytoplankton group/species (Kiorboe & Hansen, 1993), spontaneous assembly of dissolved polymers forming stable gels (Chin *et al.*, 1998), and sustained residence of aggregates in surface waters (Riebesel, 1992). Classical coagulation theory underlines three main mechanisms for particle collision, an important step in formation of aggregates: laminar and turbulent shear, Brownian diffusion and differential sedimentation. To increase their size particles have to adhere upon collision. Adhesion rate depends mainly on the stickiness of particles; thus, formation of large aggregates is determined by both quantity and quality of available particles (Alldredge & Jackson, 1995). Resistance to disaggregation and reduced settling velocity are further conditions for accumulation of aggregates in the water column. Particle spectra in the oceans were found to be in general agreement with those expected from coagulation theory (Jackson & Burd, 1998). This theory, however, appears unsatisfactory in the case of the mucilage phenomenon.

Due to the dramatic spatial extent of mucilage, some events affected areas of over 10,000 km^2 and accumulated at the surface in layers that were several cm thick (Stachowitsch *et al.*, 1990; Rinaldi *et al.*, 1995) it was suggested that mucilage-associated particulate matter reached very high values, although there were no field data to support this presumption. Variable forms and changeable vertical and horizontal distribution in the water column and at the surface make quantification of total mucilage-associated matter a very difficult task. The most promising approaches seemed to be *in situ* visual monitoring using underwater cameras (Rinaldi *et al.*, 1995), although classical methodology for assessment of suspended matter was also used (Faganeli *et al.*, 1995). Satellite remote sensing of the event in 1989 followed temporal changes of surface mucilage (Zambianchi *et al.*, 1992) while Berthon *et al.*, (2000) used a bio-optical data set collected by an off-shore oceanographic tower off Venice to study optical properties of the water column in the presence of mucilage. Neither of these studies tried to estimate the quantity of mucilage-associated particulate matter.

In order to provide quantitative estimates of mucilage accumulation in the water column and on the surface we investigated this phenomenon in the Gulf of Trieste. Using different approaches *i.e.* remote sensing, video recording and quantitative sampling we sought to quantify different forms of mucilage aggregates.

MATERIALS AND METHODS

We have made quantification of mucilage-associated suspended matter on the basis of data collected during event in early summer (June-July) of 2000.

Quantification of surfaced mucilage

The quantity of surfaced mucilage was assessed from pictures taken by video camera that was mounted on an aircraft. The eastern part of the Gulf of Trieste was over flown by helicopter and the sea surface surveyed for mucilage on 10, 11 and 14 June 2000. The survey on 14 June followed the path depicted in figure 1 (Plate I). It was carried out between 1 and 2 p.m. The height of this flight was between 400 and 500 m, and the velocity of the aircraft between 110 and 120 km h^{-1}. The snapshots of the video were taken every 15 seconds and we got 234 pictures; among them we selected 154 for further statistical analysis. The remaining pictures were not taken into account because they either partly showed land or displayed the same scenes due to aircraft manoeuvring or path repetition.

To estimate the spatial coverage of mucilage in the studied area, analysis of pictures taken from the aircraft, was carried out using two procedures. In the first, we utilized graphical software (Adobe Photoshop, Corel Photo-Paint) to manually paint mucilage areas white and the mucilageless sea surface black. The second method of picture elaboration was thresholding using the software tool ENVI for image elaboration. We used contour plot to determine the threshold between mucilage and the sea surface without mucilage, applying one contour on which we varied the levels. Before further classification of images we carried out the "decorrelation stretch" to remove the high correlation commonly found in multispectral datasets. The 'isodata' method, *i.e.* unsupervised classification was then applied to destretched images. This method calculates class means and iteratively clusters the remaining pixels using minimum distance technique (Tou, 1974). From all classified images, descriptive statistics and histograms were calculated.

Example of application of these procedures to the same situation at sea is presented in figures 2-4 showing the original video snapshot of mucilage masses at sea (Fig. 2); manual elaboration of the picture, using graphical software (Fig. 3); and corrected 'isodata' (unsupervised classification) picture after thresholding and application of decorrelation stretch (Fig. 4). Results obtained by different methods were rather similar (Tab. 1).

Tab. 1: Comparison of different methods for assessment of mucilage coverage applied to the situation in figure 2.
Tab. 1: Pokrovnost morske površine s sluzjo na primeru s slike 2 (ocenjena z različnimi metodami).

Method	Mucilage (% of surface)	Mucilageless (% of surface)
Manual separation	6.9	93.1
Thresholding	6.0	94.0
Unsupervised classification	7.0	93.0

On 11 June we also followed changes in the coverage of the sea surface by mucilage over a day (from 8 a.m. to 8 p.m.) using still photography of the same near-shore location. Pictures were elaborated manually using graphical software (Fig. 6).

Surfaced mucilage was sampled manually using 0.5 to 1.5 l polyethylene bottles for quantification of suspended matter and its quantity determined using the same procedures as for water column samples (see below).

Quantification of the water column mucilage

Field surveys, *in situ* video-recording and sampling of the water column mucilage were carried out approx. weekly from 6 June, when mucilage was first observed by divers, to 26 July, 2000, when no mucilage aggregates of any form were seen in the studied area. Field observations were most frequent from 11 to 21 June, when the mucilage event peaked in the studied area. Therefore, quantification of different mucilage forms and layers (surfaced mucilage, water column mucilage network and clouds) was based on the data collected during this period.

Sampling. Concentration of the mucilage-associated suspended matter in the water column was estimated on the basis of quantitative sampling using a peristaltic pump that was operated by SCUBA diver. While sampling, we distinguished two types of water column mucilage (Malej *et al.,* 2000): 1) loose network of mucous material stretching in layers up to 10 m thick, that were considered "quasi homogeneous suspended matter field", and 2) mucilage "clouds", that were spatially well defined and were surrounded by particle-poor water. In both cases, 35 litres of mucilage matter were sampled into large glass containers that were brought to the laboratory within one hour. Quantification of the mucilage network was derived from the premise that sampling by pump provided an average sample of the homogeneous layer. In the case of mucilage clouds our methodology provided data on particulate matter associated with these clouds. Additionally, traditional sampling using 5 L Niskin bottles at standard depths was carried out.

Analyses. Collected samples were analysed in the laboratory using the same procedure for all three types of mucilage (surfaced, mucilage network, mucilage clouds). Mucilage-associated suspended matter, that was collected in large (35 litre) containers, in all cases compacted in the surface layer. Further analysis consisted of determination of the volume of this compacted mucilage layer (cms-concentrated mucilage sample) using measuring cylinders, followed by an estimate of the remaining, presumably mucilage-free, water (mfw). Quantitative subsamples were then taken from both (cms and mfw) for suspended matter determination. The ratio of total sample volume to cms volume was calculated and used in calculation of the integrated water column mucilage-associated particulate matter. For the purposes of this paper conversion factors from volume to dry mass and carbon content of mucilage were taken from our previous study, done during the 1997 event (Flander, 1999; Malej *et al.,* 2000): mean dry mass content of mucilage was 1.6 (±0.9)% of wet mass; and mean carbon content of 10.7 (±3.2)% of dry mass.

Two examples of pictures, taken in the water column by SCUBA divers using an underwater camera, were also analysed applying the same methodology of picture analysis as for the surfaced mucilage. The method applied to water column video snapshots was unsupervised "isodata" classification (see above).

RESULTS AND DISCUSSION

Time-course of the mucilage event in 2000

In contrast to previous mucilage events in the last decade (1991 and 1997), the 2000 phenomenon appeared earlier in the season. While in 1991 and 1997 the water column mucilage accompanied by surface masses were observed in mid-July (Flander Putrle *et al.*, 2000), during the 2000 event visible mucilage has already appeared in the water column in the first days of June with surface accumulations starting from 10 June. The phenomenon reached its peak in mid-June and dissipated by mid-July. Already by 28 June some portion of mucilage has settled to the bottom and after mid-July mucilage was not observed in the water column. Mucilage completely disappeared from the studied area by the end of July. Most results used for calculation of mucilage-associated matter are based on samples collected from June 11 to 21. In this period we carried out measurements using all reported techniques (remote sensing, quantitative sampling of different mucilage forms, viderecording, standard oceanographic techniques).

Quantification of surfaced mucilage

The spatial extent of the surfaced mucilage was assessed when the phenomenon reached its culmination in the studied area, *i.e.* on 14 June. According to our previous observations, which indicated that ascension of mucilage to the surface occurred predominantly during late morning, we made our estimate of spatial coverage of the sea surface on the basis of measurements done between 1 and 2 p.m. We assumed that later during the day the quantity of surfaced mucilage did not increase significantly.

Results of descriptive statistics of 154 snapshots taken from aircraft are given in table 2 and figure 5. Only about 10% (16) images showed mucilage coverage greater than 3% and the situation presented in Table 1 and figure 2 *i.e.* about 7% coverage was rather rare. In a majority of the images (120) coverage by mucilage was less than 2% of sea surface and it was nil in 12 snapshots. Applying an overall mean coverage of 1.6% of sea surface by mucilage (Tab. 2) to the whole Gulf of Trieste (about 600 km^2) gives an estimated mucilage-covered area of about 10 km^2.

Tab. 2: Descriptive statistics of 154 snapshots, taken from aircraft on 14 June 2000.
Tab. 2: Opisna statistika obdelanih videoposnetkov površinske sluzi junija 2000.

Item	% coverage by mucilage
Minimum	0
Maximum	21.0
Mean	1.6
1st quartile (Q1)	0.3
Median	1.0
3rd quartile (Q3)	1.9
Variance	6.2
Standard deviation	2.5

Higher surface coverage was observed along shores during late afternoon hours where the surfaced mucilage accumulated because it was driven by sea breeze towards the shoreline. Figure 6 gives an indication of the variability of surface coverage by mucilage in such a near shore area. Coverage was nil before 9 a.m., increased to about 30% at 11 a.m. and reached over 50% between 01 and 02 p.m. These data indicate that past estimates, if based on near shore data, probably overestimated the quantity of surfaced mucilage. Alternately, previous events were more intense.

Wet, dry and carbon mass of surfaced mucilage. Measurements of mucilage wet mass gave rather different values for surfaced mucilage collected offshore as compared to values of more compacted mucilage that accumulated near shore. Offshore mucilage had an average wet mass of 130±2 g per litre of seawater in contrast to a significantly higher mean wet mass of that collected near shore (870±18 g per litre sea water). Applying conversion factors (dry mass to wet mass) of 1.6% and 10.7% carbon content, estimated average dry mass was 2.1 g DW/L and 0.22 g C/L for offshore surface mucilage. Respective values for mucilage that accumulated near shore were 13.9 g DW/L and 1.5 g C/L. However, these extremely high particulate mass values were limited only to top layers thinner than 0.5 cm offshore and 5 cm near shore.

Surface mucilage assessed by this technique represented only a fraction of the water column mucilage that ascended to surface. Therefore we tried to quantify particulate mass of the water column aggregations.

Quantification of the water column mucilage

Particulate matter. Average concentration of particulate matter in the water column during the mucilage event estimated on the basis of Niskin samples was 3.8±1.8 mg DW/L. Values were higher below 20 m depth (5.6±2.1 mg DW/L) than in the upper 15 m (3.0±0.9 mg DW/L). Using the conversion factor of 3% carbon to dry mass, average estimated particulate carbon was 0.1 mg C/L.

Mucilage network. Quantification of particulate matter associated with the mucilage network on the basis of sampling by pump indicated a mean mucilage wet mass of 3.5±2.6 g WW per litre seawater. Using the same conversion factors as for surface mucilage (1.6% wet to dry mass, 10.7% carbon content) we estimated that this mucilage layer on average contained 55.6±40 mg DW/L and 5.9±4.2 mg C/L. Over the time from June 10 to June 20, the wet mass of mucilage network increased from 1.2 g WW/L (2.0 mg C/L) to 7.1 g WW/L (12.1 mg C/L) indicating that "older" mucilage had a greater particulate mass per unit volume. In contrast, sampling this layer during the event using Niskin bottles gave significantly lower DW of 5.2±3.9 mg DW/L (0.2±0.1 mg C/L).

Fig. 2

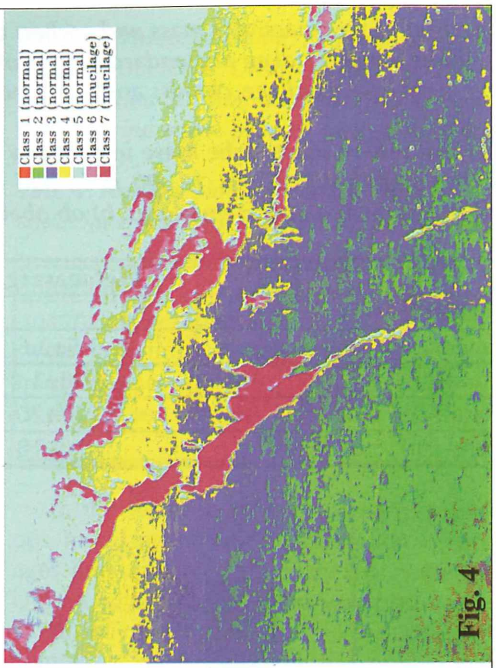

Fig. 4

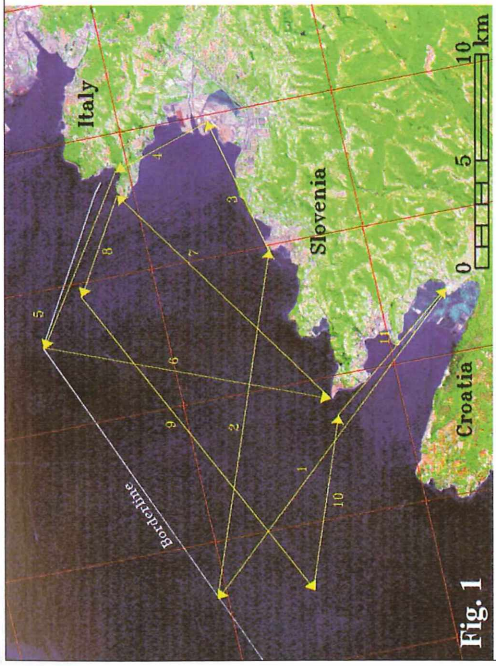

Fig. 1

Fig. 3

PLATE I / TABLA I:

Fig. 1: The helicopter flight path during video recording of the southeastern part of the Gulf of Trieste.
Sl. 1: Pot helikopterja med snemanjem površinske sluzi v jugovzhodnem delu Tržaškega zaliva.
Fig. 2: Original video snapshot of surface mucilage taken from aircraft on 14 June 2000.
Sl. 2: Originalen videoposnetek površinske sluzi 14. junija 2000.
Fig. 3: Manually elaborated video snapshot from figure 2 using graphical software.
Sl. 3: Grafično obdelan videoposnetek s slike 2.
Fig. 4: Corrected unsupervised classification ('isodata' method) - decorrelation stretched situation on Fig. 2.
Sl. 4: Prikaz površine morja z videoposnetka na sliki 2 po opravljenem klasifikacijskem postopku.

Tab. 3: Comparison of wet mass, dry mass and carbon concentrations the during mucilage event in 2000: particulate matter (Niskin samples, taken at standard depths of 0.5, 5, 10, 15, 20, m above bottom); water column mucilage: mucilage network, mucilage clouds; and surfaced mucilage: a) offshore samples, b) concentrated mucilage along shore.

Tab. 3: Primerjava mokre mase, suhe mase in ogljika v sluzi l. 2000: lebdeča snov (vzorčenje z Niskinovo posodo na standardnih globinah 0,5, 5, 10, 15, 20 m in nad dnom); sluz v vodnem stolpcu: sluzasta mreža in sluzasti oblaki; površinska sluz: a) na odprtem morju, b) ob obali.

	Wet mass (g/L)	Dry mass (mg/L)	Carbon (mg/L)
particulate matter (Niskin)		3.8±1.8	0.1±0.09
mucilage network	3.5±2.6	55.6 ±40	5.9±4.2
mucilage clouds	27.8±1.8	445±16	47.6±1.7
a) 'offshore' surfaced mucilage	120±20	2,100	220
b) 'along shore' surf. mucilage	870±18	13,900	1,500

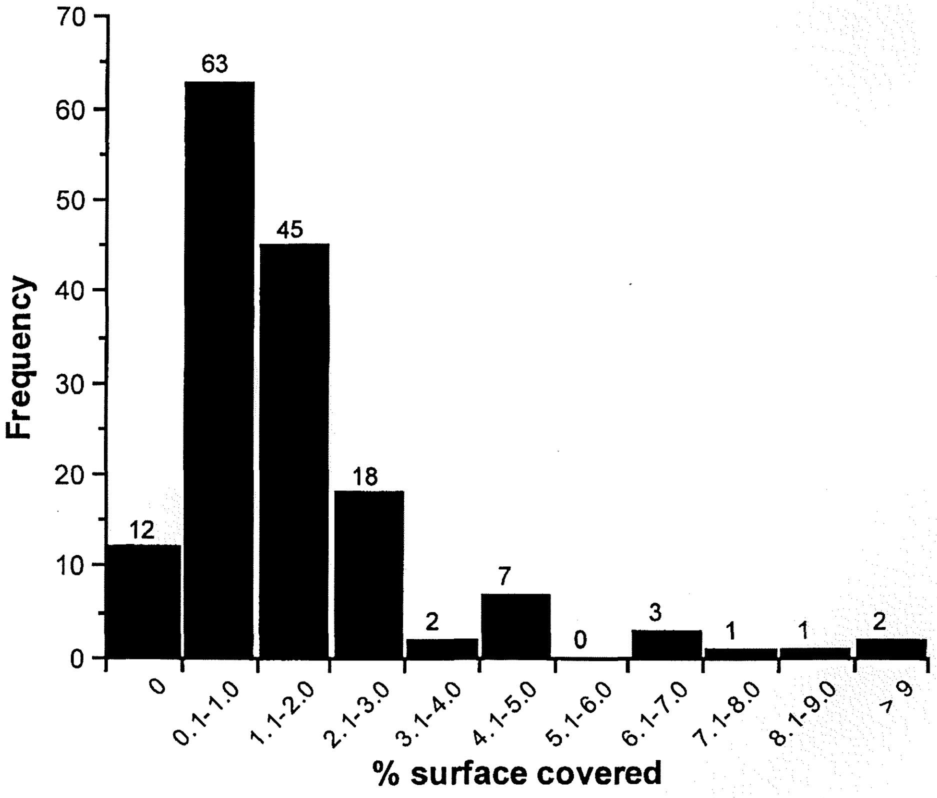

Fig. 5: Frequency distribution of results on coverage of sea surface by mucilage obtained by analysis of 154 video snapshots taken on June 14, 2000.

Sl. 5: Frekvenčna razporeditev rezultatov obdelave 154 videoposnetkov, ki kažejo pokrovnost s sluzjo 14. junija 2000.

Mucilage clouds. Wet mass values were the highest for mucilage clouds with an average of 27.8±0.8 g WW/L. Dry mass in mucilage clouds was 445±16 mg DW/L and carbon concentration 47.6±1.7 mg C/L. On one occasion (20 June; excluded from calculations of average mass) we measured extremely high wet mass (170 g WW/L) in the mucilage cloud which was similar to values of surfaced mucilage. Converting the last value to carbon indicated particulate carbon concentration in the mucilage cloud of over 290 mg C/L.

Summary of quantification of particulate mass associated with mucilage is given in table 4.

Clearly, there are rather big changes in volume-specific wet mass, dry matter and carbon for different mucilage forms that ranged over two orders of magnitude for different mucilage forms. Despite a very high volume-specific value of surfaced mucilage, its limited spatial extent (average < 2% sea surface) and concentration in very thin layer (< 0.5 cm offshore) makes its contribution to the total particulate matter unimportant.

Compared to our values, Müller-Niklas *et al.* (1994) reported significantly higher dry mass and carbon values for water column mucilage, presumably mucilage clouds, during the 1991 event: average dry weight was 1,293 mg DW/L and carbon 192.85±71.6 mg C/L. Values that they reported for water column mucilage are more comparable to our estimates for offshore surfaced mucilage.

To assess the particulate matter in the whole water layer with mucilage clouds including particle-poor surrounding water, additional information is needed: estimate of cloud size, shape and abundance. As a first approximation we defined the typical cloud as a cylinder with conical endings with an average volume of 0.25 m^2 (about 250 L). Cloud abundance was assessed by counting them in the diver's observation field, which was defined as a rotary ellipsoid that has a volume of about 1000 m^3. The number of clouds in this volume varied from nil to 8 with an average of 2. Taking into account quantitative data on carbon mass, we may estimate that the water layer with mucilage clouds had an average concentration of about 0.4 mg C/L. Due to large variability in number, size and mass of particulate matter associated with mucilage clouds this value should be considered as very approximate.

To get an overall picture of the quantity of mucilage-associated particulate matter we integrated obtained values to a 25 m deep water column using as an example the situation observed in the period from 11 to 20 June 2000. For our calculation the following depths of different layers were used: upper 4 m deep layer containing marine snow (Niskin sample), followed by a 10 m deep layer of mucilage network, 6 m deep layer comprising mucilage clouds, that usually developed below the mucilage network layer, and 5 m deep bottom layer with marine snow. Calculation of the mucilage network layer was done taking into account concentration factor of 3 x 10^{-2} (= cms/cms+mwf, see methods section). Total integrated mucilage-associated particulate carbon was estimated to be 82 g C/m^2.

Quantification of the water column mucilage using video recording and image analysis. Applying the same procedure for quantification as for surfaced mucilage, two contrasting water column situations were analysed: the marine snow layer and the mucilage network (Figs. 7, 8, Tab. 4). Results indicated that this method could be a useful supplement to the quantification methodology described above.

Tab. 4: Videorecording and image analysis of water column mucilage. Unsupervised 'isodata' classification was applied to snapshots of the water column with only marine snow present and with mucilage network (Figs. 7, 8).
Tab. 4: Analiza videoposnetkov sluzi v vodnem stolpcu: situacija z morskim snegom in sluzasto mrežo (Sl. 7, 8).

Situation	**% Mucilage**	**% Mucilageless**
marine snow (upper water column)	1.1	98.9
mucilage network (description: see methods sec.)	18.3	81.7

In the water layer considered as 'quasi homogeneous mucilage network' elaboration of underwater images thus indicated mucilage coverage less than 20%. Unfortunately, this method was unsuitable for quantification of mucilage clouds. Using average carbon concentration determined for the mucilage network and applying 20% coverage to the whole water column we obtained an estimate of mucilage-associated particulate matter an order of magnitude lower than when using the integration method of different layers (see above).

CONCLUSION

Presented estimates, based on different methodologies, indicate a very high variability in the quantity of mucilage–associated particulate matter. Contrasting values were obtained for particular mucilage forms (mucilage network, clouds, surfaced mucilage) that varied over two orders of magnitude. An additional problem is the calculation of an integrated water column value since it requires information on the vertical distribution of different mucilage forms. Therefore, only a combination of different methods used in parallel could give more reliable quantification of total mucilage-associated particulate matter.

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Fig. 6: Coverage of sea surface by mucilage in near shore area followed from 8 a.m. to 8 p.m. on June 11, 2000. Data were elaborated using the same methodology as for airborne images.
Sl. 6: Pokrovnost morja s sluzjo v priobalnem morju, ki smo jo spremljali 11. junija 2000 od jutra do večera. Slike so bile statistično obdelane z enako metodologijo kot videoposnetki s helikopterja.

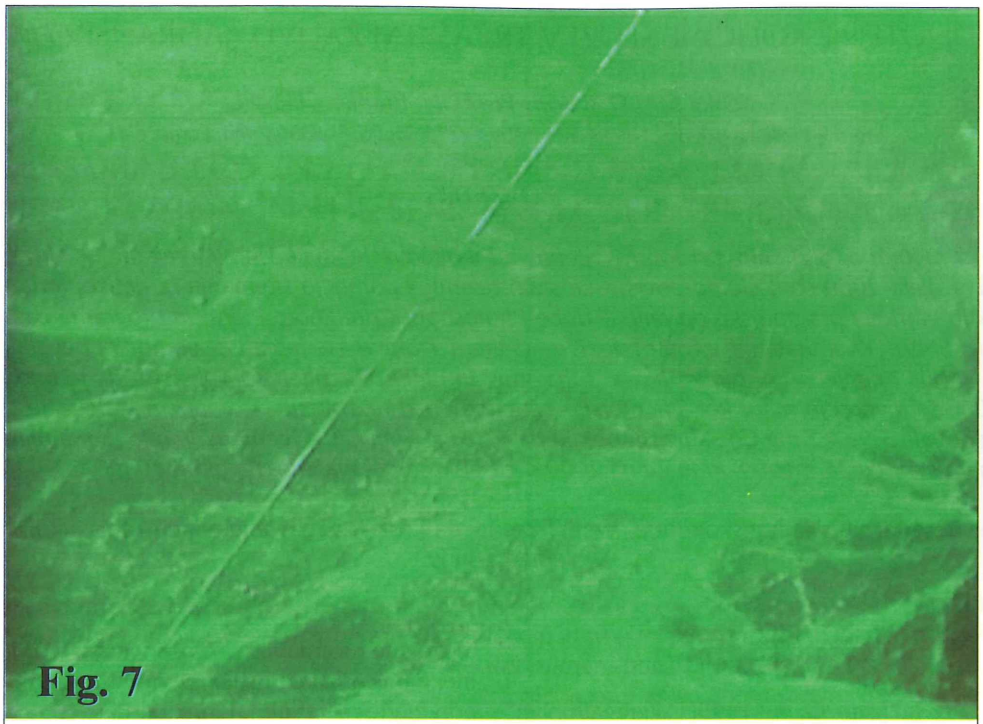

Fig. 7

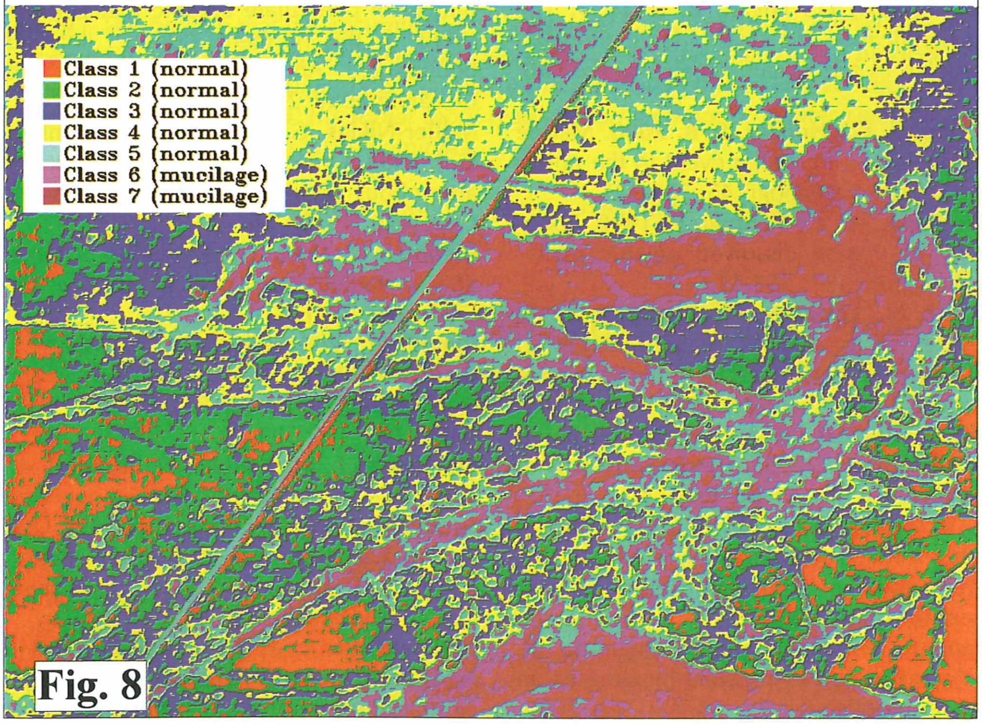

Fig. 8

PLATE II / TABLA II:

Fig. 7: Video snapshot of the water column mucilage network.
Sl. 7: Videoposnetek podvodne sluzaste mreže. Posnetek je bil obdelan z enako metodologijo kot helikopterski posnetki.
Fig. 8: 'Isodata' unsupervised classification applied to figure 7. Classification is the same as for figure 4.
Sl. 8: Obdelan videoposnetek s slike 7; klasifikacija je enaka kot na sliki 4.

OVREDNOTENJE KOLIČINE SLUZI V TRŽAŠKEM ZALIVU (JADRANSKO MORJE)

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POVZETEK

Avtorji so z uporabo različnih pristopov ocenjevali količino lebdeče snovi, vezane v sluzastih agregatih Tržaškega zaliva. Leta 2000 so količino površinske sluzi ocenili s pomočjo snemanja iz helikopterja. Slike so analizirali s pomočjo grafične programske opreme (Adobe Photoshop, CorelPhoto-Paint) in programa za analizo satelitskih posnetkov ENVI. Kvantitativne vzorce sluzi v vodnem stolpcu so jemali s pomočjo peristaltične črpalke. Količina sluzi je bila ocenjena kot mokra masa, suha snov in ogljik. Rezultati so pokazali, da je bilo med pojavom sluzi junija 2000 v povprečju manj kot 2% morske površine prekrite s sluzjo. V vodnem stolpcu je sluzasta mreža povprečno vsebovala 5,9±4.2 mg C/L, sluzasti oblaki pa 47,6±1,7 mg C/L. Ocenjena je bila tudi integrirana vrednost ogljika v vodnem stolpcu 25 metrov, ki je junija 2000 med viškom pojava znašala okoli 80 g C/m^2.

Ključne besede: sluz, Jadransko morje, kvantifikacija, daljinsko zaznavanje, video zapis, akumulacija lebdeče snovi

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SEASONAL VARIABILITY IN PHYTOPLANKTON AND BACTERIOPLANKTON DISTRIBUTION IN THE SEMI-ENCLOSED TEMPERATE GULF (GULF OF TRIESTE, ADRIATIC SEA)

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ABSTRACT

Distribution of nutrients, total carbohydrates, phytoplankton, cyanobacteria, nanoflagellates and bacterial abundance was studied simultaneously focusing on the annual cycle at two locations in the Gulf of Trieste (Adriatic Sea). The central-western area was affected by seasonal freshwater nutrient pulses from local rivers, while the eastern part was characterised by the influence of more saline/oligotrophic waters of southern origin. In 1992, spring pulse of high freshwater input was followed by diatom bloom, low bacterioplankton abundance, and increased concentration of high molecular weight carbohydrates. Due to somewhat lower freshwater inflow, there was no comparable bloom in spring 1993. We believe that the accumulation of dissolved carbohydrates occurred as a result of bacterial abundance being controlled by predators, heterotrophic nanoflagellates, rather than due to nutrient limitation or low temperature. Throughout the summer, oligotrophic conditions in the water column and the processes of transformation of organic carbon matter through a 'microbial loop' type of food web are of greater significance. At the layers bellow pycnocline, regeneration processes are dominant.

Key words: phytoplankton, cyanobacteria, heterotrophic bacteria, heterotrophic nanoflagellates, total carbohydrates, Gulf of Trieste

VARIAZIONI STAGIONALI NELLA DISTRIBUZIONE DI FITOPLANCTON E BATTERIOPLANCTON IN GOLFO SEMI-CHIUSO E TEMPERATO (GOLFO DI TRIESTE, MARE ADRIATICO)

SINTESI

In due postazioni nel Golfo di Trieste (Mare Adriatico), sono state simultaneamente studiate le distribuzioni di nutrienti, carboidrati totali, fitoplancton, cianobatteri, nanoplancton e l'abbondanza di batteri, evidenziandone il ciclo annuale. L'area centro-occidentale è risultata influenzata da apporti stagionali di nutrienti da fiumi locali, mentre quella orientale si è rivelata caratterizzata dall'influenza di acque più saline/oligotrofiche di origine meridionale. Nel 1992 l'alto apporto primaverile di acque dolci è stato seguito da fioritura di diatomee, scarsa abbondanza di batterioplancton ed elevata concentrazione di carboidrati ad alto peso molecolare. Nella primavera del 1993, in seguito a un minor apporto di acque dolci, non si è ripetuta una simile fioritura. Gli autori suppongono che l'accumulo di carboidrati disciolti si sia verificato a causa del controllo dell'abbondanza dei batteri da parte di predatori, nanoflagellati eterotrofici, piuttosto che a causa della scarsità di nutrienti o della bassa temperatura. Durante l'estate risultano maggiormente importanti le condizioni oligotrofiche nella colonna d'acqua ed i processsi di trasformazione della materia organica attraverso la rete trofica legata al ciclo microbico. I processi di rigenerazione sono dominanti negli strati sottostanti il picnoclino.

Parole chiave: fitoplancton, cianobatteri, batteri eterotrofi, nanoflagellati eterotrofi, carboidrati totali, Golfo di Trieste

INTRODUCTION

Inorganic nutrients are transformed and transported in a complex pattern in marine environments and primary production is, in most cases, limited by the availability of inorganic nitrogen or phosphorous (Dugdale & Goering, 1967; Hecky & Kilham, 1988; Currie, 1990; Thingstad & Rassoulzadegan, 1995). In many coastal marine environments, such as the northern Adriatic Sea, external riverine inputs and regeneration processes are the major sources of nutrients supporting the requirements of primary producers (Degobbis & Gilmartin, 1990).

The connection between phytoplankton dynamics and environmental fluctuations due to river runoff and seasonal stratification has been well established in temperate areas (Kiørboe *et al.,* 1990; Harding, 1994). Freshwater pulses introducing new nutrients into the marine environment are the predominant factor determining changes of phytoplankton production, biomass and community structure in the Gulf of Trieste (Malej *et al.,* 1995, 1997; Malačič *et al.,* 1997; Mozetič *et al.,* 1998), as well as in northern and middle Adriatic (Krstulović *et al.,* 1995; Harding *et al.,* 1999) and the NW Mediterranean Sea (Klein *et al.,* 1997).

Microbial communities are crucial for global biogeochemical cycles through their decomposition of organic and inorganic nutrient regeneration (Azam, 1998). Complex interaction within communities and variety of environment elements play critical role in marine biogeochemistry.

Seasonal and diel patterns of microbial abundance, production and grazing on bacteria, the main energy consumers in response to photosynthesis, have been observed in different aquatic environments (Cole *et al.,* 1988). In temperate coastal areas with substantial seasonal variation in environmental regimes, bacterial growth and numbers vary similarly (Scavia & Laird, 1987), but it is still unclear what factors determine the dynamics of the pelagic bacterial community. Seasonal bacterial growth has been shown to be limited by number of factors, such as temperature, predation, substrate supply (organic and inorganic nutrients), and viral infection (Wikner & Hagström, 1991; Caron 1991; Proctor & Fuhrman, 1992; Shiah & Ducklow, 1994; Carlson & Carol, 2001; Pomeroy & Wiebe, 2001). The relatively low variability of bacterial abundance in aquatic environments has given rise to the speculation that bacterial abundance is tightly regulated by the different factors operating on bacteria (Sanders *et al.,* 1992).

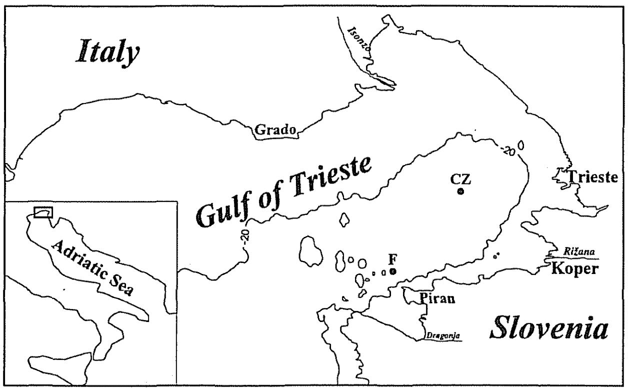

Fig. 1: Location of sampling sites (stations CZ and F) in the Gulf of Trieste (northern Adriatic Sea).
Sl. 1: Vzorčevalna mesta (postaji CZ in F) v Tržaškem zalivu (severni Jadran).

The main purpose of our study was to identify the major patterns of temporal and spatial variability of microplankton abundance at two locations in the Gulf of Trieste (Adriatic Sea). One location was affected by significant seasonal freshwater nutrient pulses from local rivers, while the second was characterised by the predominant influence of more saline/oligotrophic waters of southern origin. Water column stratification, distribution of nutrients and total carbohydrates (TCHO) were analysed in relation to phyto- and bacterioplankton abundance. In this study we draw attention to factors that influence the seasonal dynamic of bacterial communities, such as temperature, substrate availability, nutrient supply, and the effect of protistan predation.

MATERIAL AND METHODS

Sampling

Sea water samples for chemical and biological parameters were collected monthly at two locations in the Gulf of Trieste (northern Adriatic) in the period from January 1992 to December 1993 (Fig. 1). One sampling station was located in the central part of the Gulf with a water column depth of 24 m (station CZ- 45°37'24"N, 13°37'55"E), the other (station F- 45°32'18"N, 13°33' 00"E) in the south-eastern part with a depth of 21 m. Each time sea water was sampled at four to five depths (0.2, 5, 10, 15 and above bottom) using 5l Niskin bottles.

Methods

Basic hydrographical and chemical parameters - At each station, temperature, salinity, fluorescence and oxygen were recorded with a CTD probe (Fine-scale profiler, University of Western Australia, a Sea Tech Inc. fluorometer). Temperature and salinity data were used to calculate the "bulk density gradient" (c) as follows:

$$c = (\sigma_{Tb} - \sigma_{Ts})/H$$

where σ_{Tb} and σ_{Ts} are bottom and surface water densities, respectively, and H is water column depth (m).

Concentrations of inorganic nutrients were analysed in unfiltered samples using standard colorimetric methods (Grasshoff, 1976). Total carbohydrates (TCHO) were analysed in unfiltered samples using a phenol-sulphuric acid reaction with glucose as a standard (Strickland & Parsons, 1972).

Cell counts and biomasses - Cells of bacteria and heterotrophic nanoflagellates (HNAN) were counted with epifluorescence microscopy in formalin preserved (2%) water samples. Bacteria were counted after staining with DAPI according to the protocol by Porter & Feig (1980) and HNAN using primuline according to Caron (1983). Autofluorescent live cyanobacteria were counted in green excitation light (Takahashi *et al.*, 1985). Samples for phytoplankton counts were preserved with neutralised formaldehyde (1.5% final concentration). Subsamples of 50 ml were sedimented overnight and cells counted on an inverted microscope following the method of Utermöhl (1958). Chlorophyll *a* (Chl *a*) was analysed in acetone extracts using a Turner 112 fluorimeter (Strickland & Parsons, 1972).

RESULTS

Physical characteristics of the water column

The yearly mass flow of the river Soča into the Gulf of Trieste was higher during 1992, as was the inflow during the April-August period, in contrast to the lower values in 1993 (Fig. 2, top). Freshwater inputs were maximal in March-April and October-November in 1992 and October-November in 1993. This dynamics clearly affected bulk density gradient of the water column at station CZ but considerably less at the station F (Fig. 2, bottom). Water column was well mixed from December to February with minimal temperatures of about 7.0-7.5°C. Seasonal surface heating was reflected in thermal stratification, which was evident as increased bulk density gradient at both stations from May to September. Besides this broad annual peak of bulk density gradient, two additional peaks related to decreased salinity in the surface layer appeared at location in the central part of the Gulf (station CZ) in spring and autumn. Typical difference between the two stations during spring 1992 is evident also from CTD profile. The surface layer with salinities around 30 ppt at station CZ (in contrast to more than 35 ppt at station F) was characterised by high fluorescence values and increased oxygen concentration, even though that thermal stratification was not established as yet. The similar situation could be found in autumn (not shown).

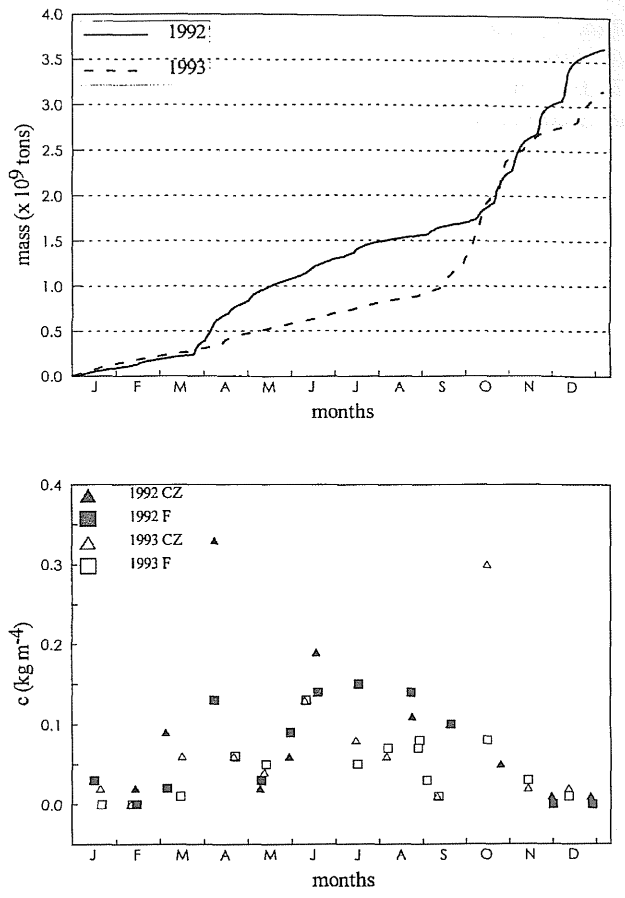

Fig. 2: The cumulative mass flow of the river Soča into the Gulf of Trieste (top) and the annual distribution of bulk density gradient (bottom) during 1992 and 1993.
Sl. 2: Kumulativni vnos mase sladke vode iz reke Soče v Tržaški zaliv (zgoraj) in letna porazdelitev gostotnega gradienta (spodaj) v letih 1992 in 1993.

Seasonal distribution of nutrients and phytoplankton

In 1992, the distribution of nitrate from January to April showed a marked surface peak, decreasing below 5 m depth (Fig. 3). The concentrations of nitrate increased up to 15.12 µM at station CZ and 8.57 µM at station F in spring 1992 and were rather high during the same period in 1993 (up to 8.53 µM).

In contrast to nitrate, ammonium (Fig. 4) and phosphate (data not shown) concentrations showed bottom maximum (5.85 and 0.59 µM, respectively) during summer-early autumn in both years. These peaks were especially evident at station CZ indicating regenerative processes. Silicate concentrations displayed similar trend in bottom layer as did ammonium and phosphate, with peak value 13.99 µM of silica at station CZ in August 1992. At the surface, silicate winter concentrations around 5-6 µM were reduced soon to concentrations below 2 µM parallel to the development of the spring diatom bloom.

The nutrient input caused an accumulation of phytoplankton biomass in March-April 1992, with chlorophyll levels of up to 7.32 µg Chl *a* l^{-1} at station CZ and 3.50 µg

Tab. 1: Two-year (1992-1993) average and maximum concentrations of selected nutrients, phytoplankton biomass (Chlorophyll a), bacterial, cyanobacterial and nanoflagellate (HNAN) abundance at stations F and CZ.

Tab. 1: Dvoletna (1992-1993) povprečja in najvišje koncentracije izbranih hranil, fitoplanktonske biomase (klorofil a), bakterijske, cianobakterijske in nanoflagelatne abundance na postajah F in CZ.

	station F		station CZ	
	average	max	average	max
Phosphate (μM)	0.15±0.13	0.60	0.13±0.1	0.45
Nitrate (μM)	1.84±1.36	8.57	2.02±2.29	15.12
Ammonium (μM)	1.49±0.90	5.96	1.56±0.94	5.85
Chlorophyll *a* (μg l^{-1})	0.90±0.63	3.85	1.14±1.0	7.32
Bacteria (cells l^{-1})	4.4x10^{8}±3.0 x10^{8}	1.7 x10^{9}	6.9 x10^{8}±4.3 x10^{8}	1.9 x10^{9}
Cyanobacteria (cells l^{-1})	1.2x10^{7}±1.4 x10^{7}	5.8 x10^{7}	3.3 x10^{7}±3.2 x10^{6}	7.6 x10^{7}
HNAN (cells l^{-1})	9.2x10^{5}±9.3 x10^{5}	6.1 x10^{6}	1.2 x10^{6}±7.1 x10^{5}	3.2 x10^{6}

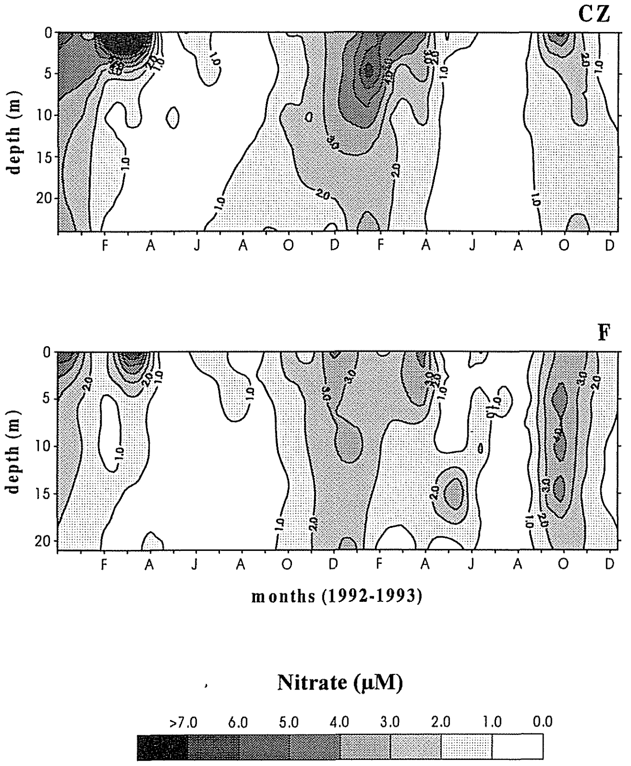

Fig. 3: Temporal and vertical distributions of nitrate concentrations at stations CZ and F during 1992 and 1993 (* the different shades of black in the figure correspond to the different concentrations).

Sl. 3: Časovna in globinska porazdelitev koncentracij nitrata na postajah CZ in F v letu 1992 in 1993 (* različna intenziteta črne barve na sliki ustreza različnim koncentracijam).

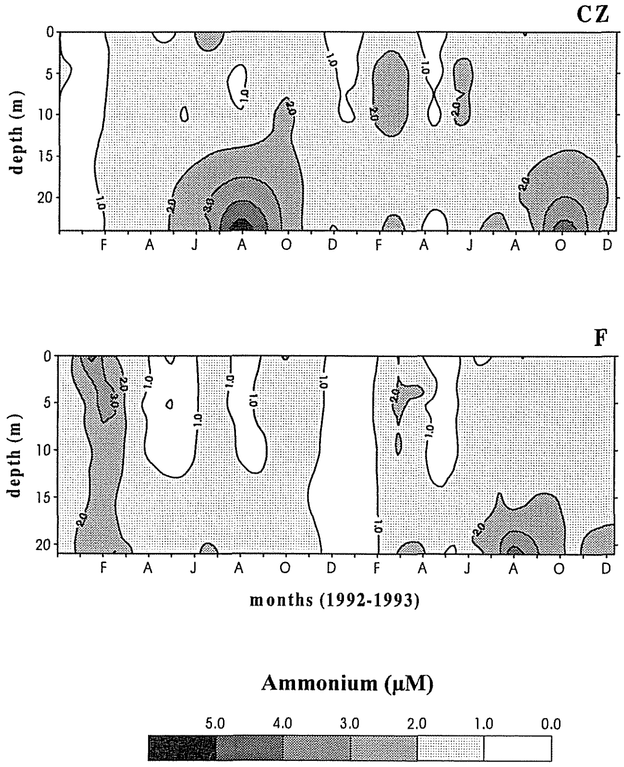

Fig. 4: Temporal and vertical distributions of ammonium concentrations at stations CZ and F during 1992 and 1993. (* see comment at figure 3).

Sl. 4: Časovna in globinska razporeditev koncentracij amonija na postajah CZ in F v letih 1992 in 1993. (* glej razlago pri sliki 3).

Chl *a* l^{-1} at station F (Fig. 5). Among eucaryotic plankton, diatoms dominated winter-early spring bloom 1992 (Fig. 6), with a peak of 8.33 x 10^6 cells l^{-1} and 3.49 x 10^6 cells l^{-1} at stations CZ and F, respectively.

The stratification of water column developed later in May, when low concentrations of phytoplankton biomass were measured throughout the water column (0.49-0.94 µg Chl *a* l^{-1}) at both stations and in both years. Microflagellates and cyanobacteria reached peak abundance in August-September in both years. In 1993, additional seasonal peaks of cyanobacteria were observed in May, followed by a decrease in June and July (Fig. 7a), and in November. The numbers varied between 0.85 x 10^7 to 7.55 x 10^7 cells l^{-1} at station CZ and from 0.59 x 10^7 to 5.80 x 10^7 cells l^{-1} at station F, and higher abundance was recorded in 1993. An additional input of nutrients in October-November along with autumn cooling, stronger winds, and mixing of the water column provoked a second diatom bloom. This winter-spring diatom bloom was more evident at station CZ in 1992 (phytoplankton biomass up to 2.28 Chl *a* µg l^{-1}) but less obvious in 1993.

In general, the yearly mean and maximum concentrations of inorganic nutrients (except phosphate) and the chlorophyll biomass were lower at station F in comparison to concentrations at station CZ (Tab. 1).

Annual distribution of heterotrophic pelagic bacteria and nanoflagellates

In 1992, the annual dynamic of heterotrophic bacterial abundance showed two peaks, one in January and the other in mid-September, in comparison to consistent increase of bacterial abundance in 1993 up to the October maximum (Fig. 7b). In the winter period, the bacterial abundance declined sharply in February, when seawater reached the lowest temperature. Bacterial numbers varied between 0.24 x 10^8 and 1.72 x 10^9 cells l^{-1} at station F and 0.48 x 10^8 and 1.89 x 10^9 cells l^{-1} at station CZ.

Throughout the water column, heterotrophic bacteria were uniformly distributed in the winter-spring period. During the summer, the high concentrations were recorded in the upper 10 meters, while in September and October the highest values were found above the bottom. High bacterial abundance above the bottom cooccurred with a peak of ammonium (r^2=0.43, $p<0.001$) during the same months.

The vertical distribution of heterotrophic bacteria followed similar seasonal pattern at both stations. The yearly maximum concentration was lower at station F in comparison to concentration at station CZ (Tab. 1). On a yearly basis, there was a significant correlation between bacterial abundance and temperature (r^2= 0.62, $p<0.001$), and no correlation between bacterial abundance and Chl *a* concentration or inorganic nutrients, with exception of ammonium at the bottom level. Minimal bacterial abundance coincided with the end of spring Chl *a* maximum.

Both cyanobacteria and heterotrophic bacteria showed a decline when HNAN dominated. In our samples, nonpigmented HNAN, such as chrysomonads, were the dominating species. The number of HNAN ranged from 0.11 x 10^6 to 6.15 x 10^6 cells l^{-1} (Fig. 7c). The maximum concentration was recorded in June and September in 1992, while in the following year abundance was lower (up to 2 x 10^6 cells l^{-1}), with peaks in May-June, August, and November. Although the composition of the HNAN fauna varied during the study period, some groups remained important throughout the year. The most common forms were flagellates with a length between 1 and 5 µm. The composition of this fauna was dominated by non-pigmented chrysomonads with an average volume of 15.8 µm³. Smaller types, such as a bicoecid flagellate with an average volume between 1 and 3 µm³ , were constantly present, constituting up to 33% of the total counts.

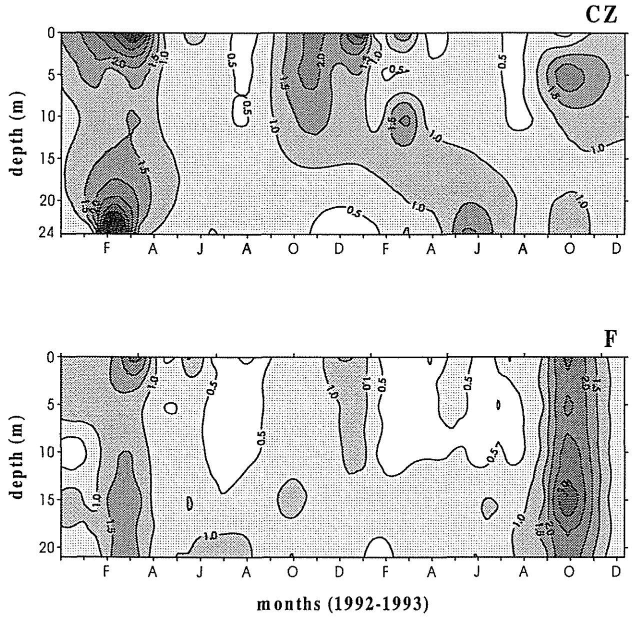

Fig. 5: Temporal and vertical distribution of phytoplankton biomass (Chl a) concentrations at stations CZ and F during 1992 and 1993. (* see comment at figure 3).

Sl. 5: Časovna in globinska razporeditev fitoplanktonske biomase (Chl a) na postajah CZ in F v letih 1992 in 1993. (* glej razlago pri sliki 3).

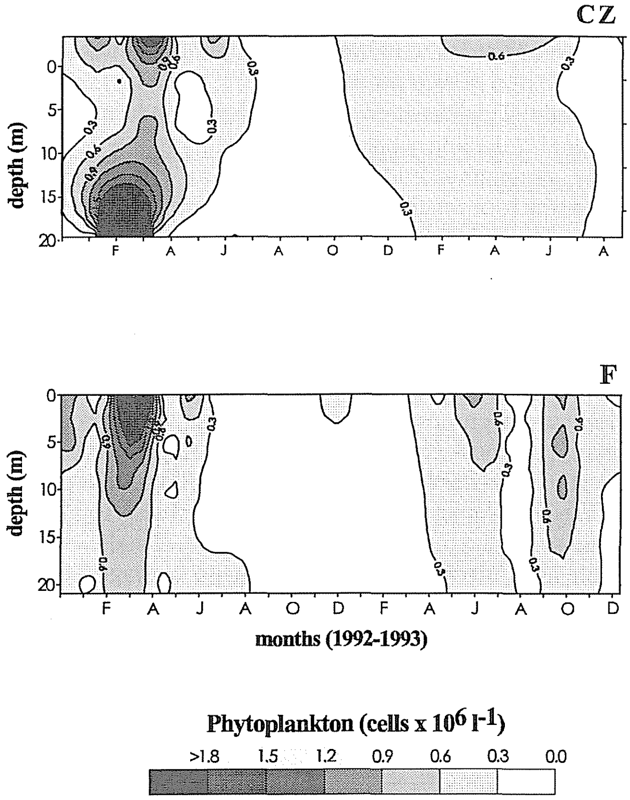

Fig. 6: Temporal and vertical distributions of phytoplankton abundance at stations CZ and F during 1992 and 1993. (* see comment at figure 3).

Sl. 6: Časovna in globinska razporeditev fitoplanktonske abundance na postajah CZ in F v letih 1992 in 1993. (* glej razlago pri sliki 3).

Variations in total carbohydrates concentrations (TCHO)

Concentrations of total carbohydrates were low (< 150 µg l^{-1}) and showed little variability in the bottom layer at both stations and throughout the studied period (Fig. 8). The upper water column exhibited rather different dynamics during the two years of our study: in 1992, very high values were determined in February-March period, which were presumably related to a diatom bloom (Chl *a* > 7 µg l^{-1}, abundance > 8 x 10^6 cells l^{-1}). There was no comparable bloom in 1993 and TCHO concentrations were low during winter-spring. In 1993, higher values were measured during the summer (July-August). Fractionation of TCHO into high and low molecular fraction was carried out only when values over 200 µg l^{-1} were determined, *i.e.* in February-March 1992 and July-August 1993. While February-March high concentrations of TCHO were predominantly high molecular weight carbohydrates (ratio HMW:LMW > 3), summer high concentrations were characterised by dominance of low molecular weight carbohydrates (HMW:LMW < 0.5).

DISCUSSION

In this study we have followed distribution and abundance of phytoplankton, cyanobacteria and heterotrophic bacteria, simultaneously focusing on the annual cycle at two locations in the Gulf of Trieste (Adriatic Sea). The Gulf of Trieste is a semi-enclosed gulf with the main freshwater inputs from its north-western coast (annual average flow about 150 m^{3}s^{-1} (Olivotti *et al.*, 1986) and peaks over 1000 m^{3}s^{-1} (Malačič *et al.*, 1997)). The general circulation pattern is predominantly counter clockwise in the lower layer and of variable size in the surface layer. This circulation can be modulated by prevailing winds (Stravisi, 1983). The physiography of the area includes a limited water exchange and low river inflow, especially during the summer. These conditions may therefore strongly influence the nutrient balance and the succession of plankton organisms.

During the course of our study, we encountered two contrasting situations. In 1992, a marked late winter-early spring freshwater input caused intense diatom bloom in the central-western area of the Gulf (station CZ) but reaching also the eastern part (station F). On the other hand, the winter-spring freshwater inflow during 1993 affected the central part of the Gulf of Trieste only slightly and consequently the winter-spring phytoplankton biomass was modest throughout the Gulf. Situation during autumn of both years was quite similar, although the effect of freshwater input seemed to be more marked in 1992.

Typically, the upper part of the water column in the centre of the Gulf had higher phytoplankton biomass and diatoms were more important taxa than in the eastern area, reflected also in the prevalence of fucoxantin over other accessory pigments (Terzić *et al.*, 1998). Such conditions were particularly evident during the winter-spring of 1992 with more abundant freshwater inputs.

The higher fluorescence in the deeper water column at station CZ was related to sinking of late winter diatom bloom as indicated by similarity of taxonomic composition between this community and surface one from previous month. Similar, few meters deep fluorescence humps were usually recorded from April to October at varying depths (16 to 23 m) and were much more prominent at station CZ than F. Clearly, the station F was less influenced by freshwater inputs.

Oligotrophic conditions in the water column above the pycnocline supported lower phytobiomass and prevalence of cyanobacteria, small eucaryotes and heterotrophic bacteria in both summers throughout the Gulf. The layer below pycnocline was characterised by regenerated and rather high nutrient concentrations. In this layer, phytobiomass was higher than at the surface dominated by large algae (>8 µm). The period of maximum concentration of ammonium above the bottom coincided with the low oxygen in the overlying water

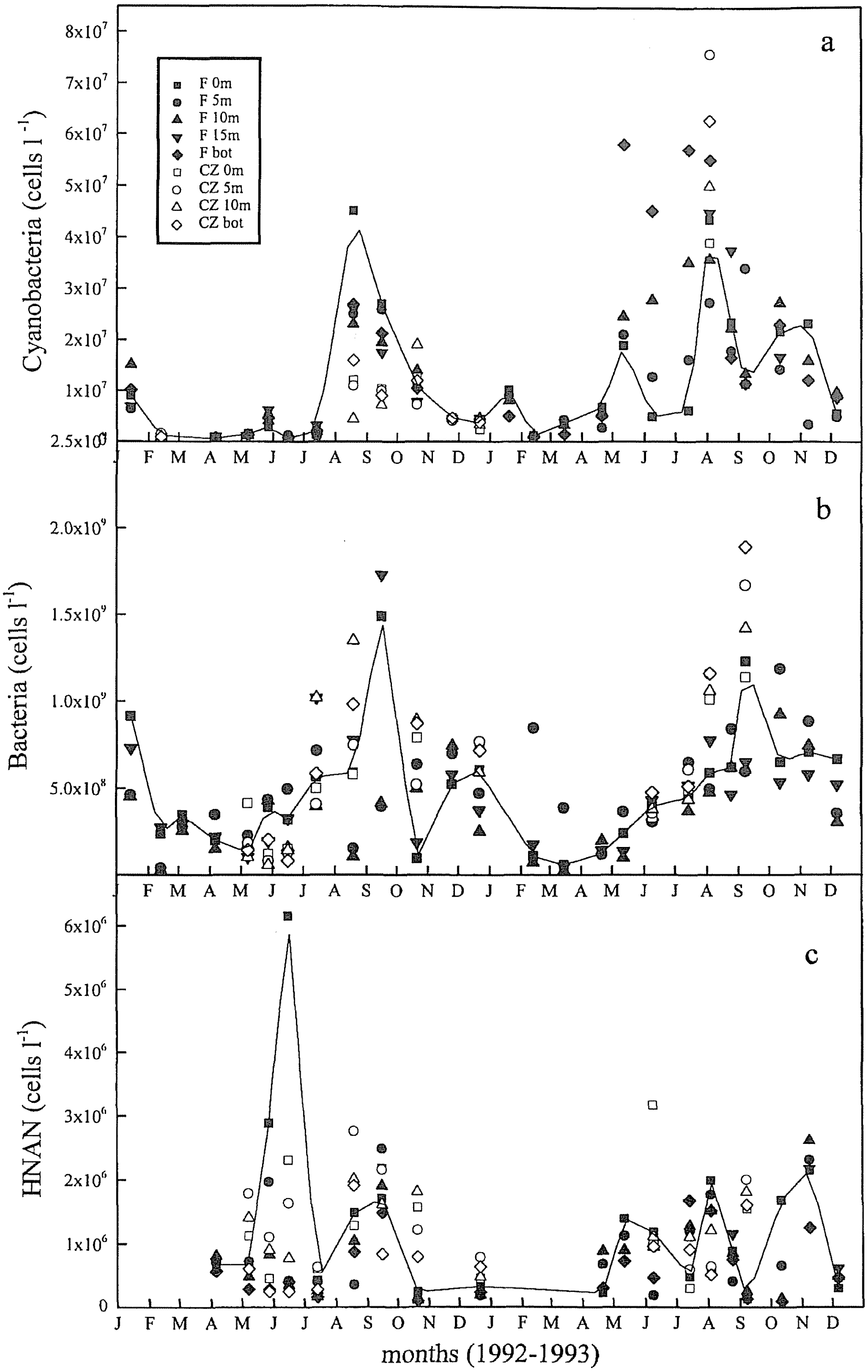

Fig. 7: Seasonal distribution of cyanobacteria (a), heterotrophic bacteria (b) and heterotrophic nanoflagellates HNAN (c) at different depths at stations F and CZ in the Gulf of Trieste during 1992 and 1993.
Sl. 7: Sezonska razporeditev cianobakterij (a), heterotrofnih bakterij (b) in heterotrofnih nanoflagelatov (HNAN) (c) na različnih globinah postaj F in CZ v Tržaškem zalivu v letih 1992 in 1993.

(<40% saturation) and high abundance of heterotrophic bacteria. The influence of processes occurring at the interface of marine sediment and overlying water on organic carbon and nitrogen cycling was recorded also in previous years in the shallow Gulf of Trieste (Faganeli, 1983; Turk, 1992; Kemp & Faganeli, 1999).

In a course of two years, a marked seasonal variability of marine unicellular cyanobacteria bacterioplankton community, and HNAN occurred. The abundances were within the range reported from other areas, *e.g.* Adriatic Sea (Krstulović & Šolić, 1990; Fuks, 1995), English Channel (Linley *et al.,* 1983), Chesapeake Bay (Malone *et al.,* 1994), NE coast of USA and South California (Fuhrman & Azam, 1982), Kiel Bight (Meyer-Reil, 1977), Mediterranean Sea (Hagström *et al.,* 1988). On a seasonal scale, the changes in the population size of the entire heterotrophic bacterial community were within a factor of 50%. Seasonality of bacterioplankton species was shown recently by several investigators, using whole-genome probes (Pinhassi & Hagström, 2000; Hagström *et al.,* 2000; Fandino *et al.,* 2001). The community of heterotrophic bacteria in the sea is dominated by relatively few species undergoing regular, repeatable seasonal successions. Although different bacterial phylotypes are dominant in different seasons, single species might persists at high abundance for long periods (up to several weeks) (Rehnstam *et al.,* 1993).

Marine bacteria are non-randomly distributed vertically and horizontally as response to concentration gradients in microenvironments. Some of the factors, such as substrate composition, temperature changes and grazing pressure, which influence the growth of bacteria have been subject to control the intra-annual variability.

In the Gulf of Trieste, bacterial abundance declined sharply when the lowest temperature was measured in February in both years. Since spring phytoplankton bloom begins while the water is still near its yearly minimum temperature, bacterial growth and activity could be inhibited by low temperature. A positive correlation between temperature and bacterial abundance was established during this study, and had been observed in other aquatic environments, especially during the non-summer seasons (Siah & Ducklow, 1994; Pomeroy & Wiebe, 2001). The higher relative importance of temperature over substrate has been observed when substrate supply was not limiting for bacteria growth (Shiah & Ducklow, 1994). In our measurements, spring phytoplankton bloom was followed by low phosphate and nitrate concentration throughout the water column and by an increase of TCHO concentration, predominantly due to high molecular weight fraction in February-March 1992. The lag in bacterial abundance, which occurred and marked dispersion or accumulation of phytoplankton-derived TCHO, must have taken place before being taken up by bacteria. The ability of bacteria to use carbon-rich substrate has been limited when phosphorous was lacking in our control enrichment experiments (Fajon *et al.,* 1999). Similar results were found also in other marine waters when accumulation of dissolved organic carbon occurred when bacterial growth was limited by inorganic nutrients (Williams, 1995; Thingstad & Lignell, 1997).

However, interaction of temperature with substrate availability on bacterial dynamic was evident, a lag phase in biomass increase may reflect the presence of predators - HNAN. Both cyanobacteria and heterotrophic bacteria showed a decline when HNAN dominated. HNAN abundance increased after the spring bloom of diatoms in 1992, and abundance was 3 times higher compared to the following year. The majority of the bacterial biomass could be utilised by protozoa, as shown by previous measurements of HNAN and the recorded grazing on bacteria in our laboratory and *in situ* experiments (Turk *et al.,* 1992; Turk & Hagström, 1997). The importance of protozoan grazing on bacteria has been stressed in different marine environments (Wikner & Hagström, 1991; Šolić & Krstulović, 1994; Šolić *et al.,* 1998).

During the summer stratification period, the organisms of microbial food web dominate the plankton population throughout the water column. High concentrations of TCHO, characterised by dominance of low molecular weight carbohydrates (August 1993), cooccurred with high abundance of heterotrophic bacteria, hence, the processes of transformation of organic carbon matter through a 'microbial loop' type of food web might be more important.

In the results discussed above we have demonstrated the influence of an initial pulse of freshwater from local river at the station in the central-western area of the Gulf on physical, chemical and biological parameters, compared to the other station, which is characterised by predominant influences of more saline/oligotrophic waters of southern origin. In two consecutive years, different pattern of phytoplankton and bacterioplankton seasonal distribution occurred, due to main factors controlling their distribution, such as different pulses of freshwater derived nutrients or control by predators.

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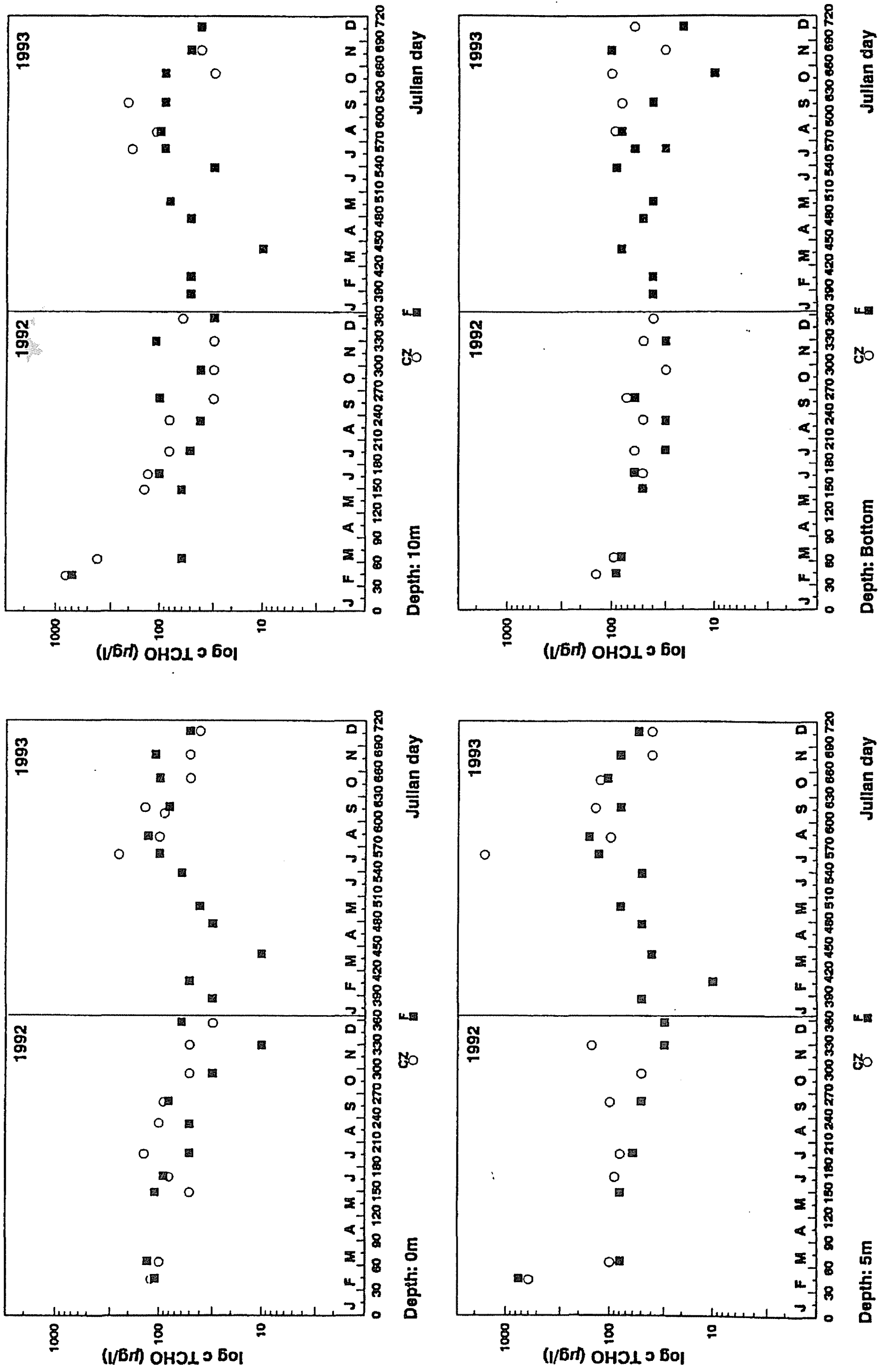

Fig. 8: Seasonal variation in total carbohydrates concentration at different depths at stations CZ (O) and F (●) in the Gulf of Trieste during 1992 and 1993.

Sl. 8: Sezonske spremembe koncentracij celokupnih ogljikovih hidratov na različnih globinah postaj CZ (O) in F (●) v Tržaškem zalivu v letih 1992 in 1993.

SEZONSKA RAZPOREDITEV FITOPLANKTONA IN BAKTERIOPLANKTONA V POLZAPRTEM ZALIVU (TRŽAŠKI ZALIV, JADRANSKO MORJE)

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POVZETEK

Predstavljena je prostorska in časovna razporeditev hranilnih soli, celokupnih ogljikovodikov, abundance fitoplanktona, cianobakterij, heterotrofnih nanoflagelatov in bakterij na dveh postajah Tržaškega zaliva (severni Jadran) v letu 1992 in 1993. Spomladanski vnos hranilno bogate sladke vode povzroči naraščanje števila kremenastih alg predvsem v centralnem delu zaliva, medtem ko so koncentracije klorofila nižje in vrstna sestava fitoplanktona v vzhodnem delu Tržaškega zaliva pod vplivom oligotrofnih vod južnega Jadrana. Ta razlika je bila opazna posebno v zimsko-spomladanskem obdobju leta 1992. Po spomladanskem cvetenju kremenastih alg v letu 1992 so bile izmerjene povišane koncentracije celokupnih ogljikovih hidratov, predvsem visoko-molekularne frakcije. Število heterotrofnih bakterij je v pozno pomladanskem obdobju nizko, kar je verjetno posledica številnih dejavnikov, kot so temperatura, razpoložljiva količina in vrsta substrata ter predacija heterotrofnih nanoflagelatov. Čeprav so potrebni dodatni podatki za zanesljivejše vrednotenje rezultatov raziskave, le-ti kažejo, da dinamiko populacije heterotrofnih bakterij kontrolirajo v veliki meri predatorji, heterotrofni nanoflagelati.

Poleti, v obdobju stratificiranega vodnega stolpca, prevladujejo mikroflagelati, enocelične cianobakterije, heterotrofne bakterij in so pomembni procesi transformacije organske snovi preko "mikrobne prehranjevalne zanke". V območju pod piknoklino prevladujejo regeneracijski procesi in razmeroma visoke koncentracije hranilnih soli (amonija) se ujemajo z nizkimi koncentracijami kisika in visokim številom heterotrofnih bakterij.

Ključne besede: fitoplankton, cianobakterije, heterotrofne bakterije, heterotrofni nanoflagelati, hranila, celokupni ogljikovi hidrati, Tržaški zaliv

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IMPACTS OF NET CAGE FISH FARM ON SEDIMENTARY BIOGEOCHEMICAL AND MEIOFAUNAL PROPERTIES OF THE GULF OF TRIESTE

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ABSTRACT

This study provides basic information about the impacts of a fish farm activity on the Slovenian coastal sea. Samples were collected from the fish farm area (sampling site-SS) and away from the cages (control site-CS). Environmental changes were most evident in benthos showing a long-term impact on meiofauna communities. The meiofauna examination and pore water concentrations of hydrogen sulphide and sulphate indicate the greatest impact directly under the cages. The sedimentation of total suspended matter, particulate organic carbon and total particulate nitrogen in the fish farm region was greater than that at unimpacted area. The lower C/N ratio of fish farm suspended matter results from greater supply of proteinaceous material. However, the C/N ratio of sediment under the cages suggests that the system could be in a quasi steady state, where removal processes balance the organic matter loading from the cages. The values of $\delta^{13}C$ *and* $\delta^{15}N$ *of fish were similar to those in dry food pellets fed to the sea bass* (Dicentrarchus labrax) *indicating their primary source of food.*

Key words: fish farm, $\delta^{15}N$, $\delta^{13}C$, sediment trap, sediment, meiofauna

IMPATTO DELLA PESCICOLTURA IN GABBIE FLOTTANTI SULLE PROPRIETÀ BIOGEOCHIMICHE DEL SEDIMENTO E SULLA MEIOFAUNA DEL GOLFO DI TRIESTE

SINTESI

Lo studio fornisce informazioni sull'impatto della pescicoltura in acque costiere slovene. I campioni sono stati raccolti nell'area interessata dall'attività (sito SS) e fuori da questa (stazione di controllo CS). I maggiori cambiamenti ambientali sono stati registrati a livello del benthos, con impatti a lungo termine sulle comunità meiofaunistiche. L'analisi della meiofauna e le concentrazioni di idrogeno solforato e di solfato nelle acque interstiziali del sedimento indicano un impatto maggiore direttamente sotto le gabbie. La sedimentazione della materia sospesa totale, del particolato di carbonio organico e del particolato di azoto totale è risultata maggiore nell'area interessata dalla pescicoltura che in quella non affetta. Il minor rapporto C/N della materia sospesa proveniente dalle colture indica un apporto maggiore di materiale proteinaceo. Dal rapporto C/N del sedimento sottostante le gabbie si può ipotizzare che il sistema sia in uno stato semi-stabile, dove i processi di rimozione bilanciano la materia organica proveniente dalle gabbie. I valori di $\delta^{13}C$ *e* $\delta^{15}N$ *nei pesci sono risultati simili a quelli riscontrati nel mangime secco, fonte primaria di nutrimento per la spigola* (Dicentrarchus labrax).

Parole chiave: pescicoltura, $\delta^{15}N$, $\delta^{13}C$, trappole per sedimento, sedimento, meiofauna

INTRODUCTION

The rapid development of different aquacultures in the world has resulted in several studies directed towards assessment of the environmental impacts of this activity (Hargrave *et al.*, 1997). During recent years there has been a significant increase in the number of fish farms established in Mediterranean waters. Below the fish cages, organic matter (OM) originating in fish-food remains and the excreta of the cultured fish often accumulates in the sediment. Enhanced and constant sedimentation of particulate organic waste products results in anoxia, high levels of hydrogen sulphide in sediments and subsequently in alteration of the benthic community and a reduction in bioturbation processes. Enhanced aerobic and anaerobic microbial activity in organically rich sediments is resulting in oxygen depletion, production of toxic substances such H_2S, and low oxidation-reduction potentials are characteristic of anaerobic marine sedimentary environments (Weston, 1990). Hydrogen sulphide produced by sulphate-reducing bacteria, through anaerobic respiration stimulated by available substrate and increasing temperature during early summer, could accumulate within sediments to levels that are toxic to benthic macrofauna and heterotrophic microfauna (Hargrave *et al.*, 1993). Oxidation of H_2S, produced during the anaerobic decomposition of organic matter by sulphate-reducing bacteria, is thought to be the major source of the chemical oxygen demand in marine sediments (Findlay & Watling, 1997). Hydrogen sulphide is also toxic to fish and out-gassing of this from sediments beneath fish cages could have a detrimental effect on fish health (Gowen & Bradbury, 1987). Regardless of the pathway of organic matter

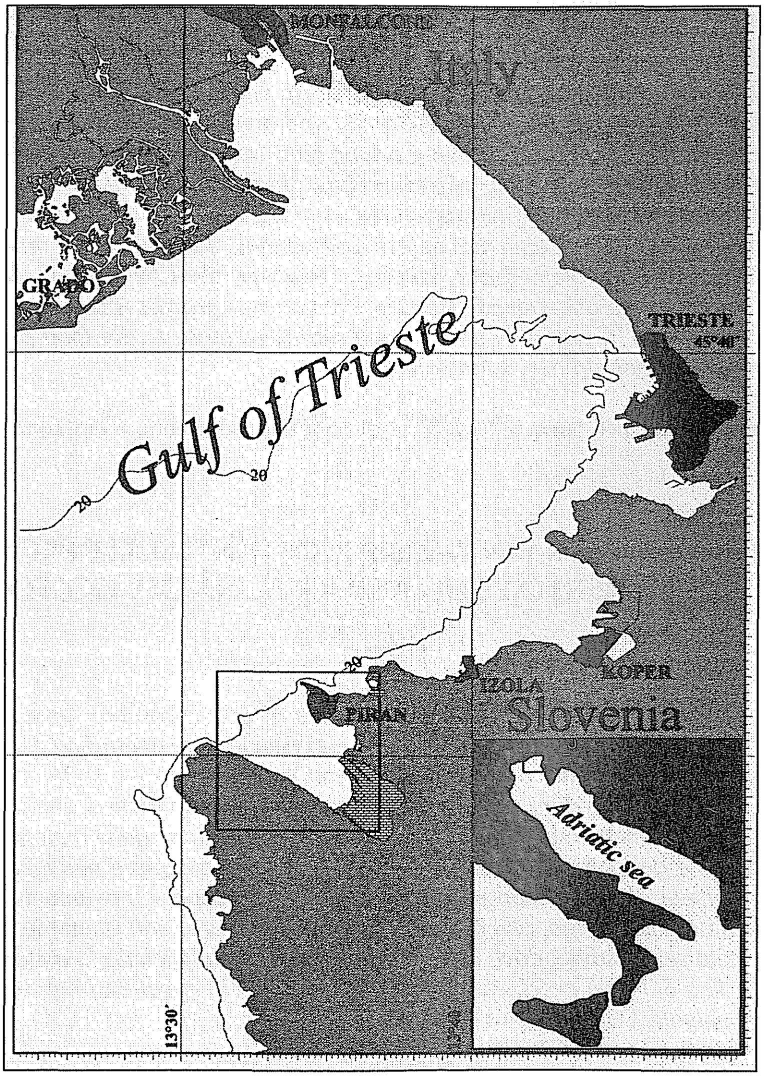

Fig. 1: Map of the Gulf of Trieste (northern Adriatic Sea).
Sl. 1: Lokacija Tržaškega zaliva (severni Jadran).

decomposition, if the supply of oxygen is sufficient then hydrogen sulphide will not accumulate within surficial sediments (Findlay & Watling, 1997).

The degree of impact depends on many factors such as water current speed and direction, sediment composition, resuspension, benthic fauna and organic loading from fish farm activity (Hargrave *et al.,* 1997). Nevertheless, organic output from the fish cages is a serious source of pollution in the affected marine areas. Consequently it is very important to trace organic matter fluxes and estimate their impact on the generally oligotrophic Slovenian marine environment.

In order to provide basic information about the impacts of fish farm area in the Slovenian coastal sea and to collect necessary data for the determination of the carrying capacity of the ecosystem and sustainable management of the investigated area, we performed the preliminary study represented by IAEA Research Contract (Environment Programme - UNEP).

MATERIAL AND METHODS

Study sites

The fish cage farm is located in coastal marine waters in Piran Bay - Gulf of Trieste (Northern Adriatic) (Fig. 1). The pilot cage facilities were established in 1988. From 1989, sea bass *(Dicentrarchus labrax)* and sea bream *(Sparus aurata)* have been the commercially cultivated species. The bottom depth at the fish farm is 12 to 13 m. In the fish farm a series of round cages (eight of 8 m in diameter, and eight of 12 m in diameter) have been used for production of fish. The depth of net cages is about 4.5 m. The fish were fed commercial pelted fish food (Marico Start Premium). There is a minor freshwater input from a local stream discharging into the sea about 1.5 km from the fish farm. The water of the Gulf of Trieste is stratified from the spring to the end of summer. The Gulf is characterized by large temperature variations (6-26°C in the surficial layer and 6-20°C above the bottom). Surface salinity ranges from 33 to 37.5 PSU and bottom water salinity from 36 to 38.5 PSU. Water circulation in the farm area is sufficient to keep the bottom oxygenated throughout the year.

The surficial sediment at the study site is dark grey sandy clayey silt (Ogorelec *et al.,* 1991) containing up to 20% of sand and up to 35% of clay. With respect to the control site (CS), it is slightly richer in sand and contains less clay, due to the near mouth of the river Dragonja. The carbonate content is above 30%. Ostracods, molluscs and foraminifers are the most frequent biogenic components of the sediment. The majority of carbonate minerals is of detrital origin. This is true for quartz, too, and is the third most abundant mineral; its content reaches up to 20%. The clay minerals at the study site are composed of chlorite and mixed structure illite/montmorillonite. Pyrite observed in the sediment at about 4% indicates reducing conditions and it is normally present in up to 200 μm large framboids few millimetres below the surface.

Sampling

The samples were collected during a 24 hour long sampling period on 21 and 22 June 2000 at the sampling site (three samplings: morning of first day - sampling I, midnight sampling II and morning of second day - sampling III) and at the control station (two samplings: morning of first day - sampling I and second day - sampling III). The sampling site (SS) was located under the cages of sea bass and the control site (CS) at a similar depth was established 1.5 kilometres from the fish farm (Fig. 2).

Sediment cores (5 cm in diameter) were collected by SCUBA divers at sampling and control sites. Cores were inserted into the sediment to preserve an intact sediment-water interface and plastic rubber stoppers were used to close the top and bottom of each core. Surficial sediment (0-2 cm) was used for subsequent analyses. For meiofauna analyses three replicate tube core samples (3.2 cm in diameter) were used.

The sedimentation rates were measured over a period of 24 hours using moored sediment traps, which were designed to collect 3 samples simultaneously. Cylindrical sediment traps with a diameter of 7 cm and an aspect ratio of 7 were used to collect sinking particles from the cages (positioned below the cages approx. 1 m above the bottom). At the same time, sedimentation rates were also measured at the control site (1.5 km from the influenced area). After collection, three aliquots of homogenized suspension from each cylinder were filtered through precombusted Whatman GF/F glass micro-fibre filters. All samples were freeze-dried for 24 hours and weighed. Dried samples were used for analysis of total suspended matter (TSM), particulate organic carbon (POC), particulate nitrogen (PN) and isotopic composition (^{13}C and ^{15}N).

Samples of fish, fish food, fish cage fouling were also collected for stable isotope analysis (^{13}C and ^{15}N). Different fish tissues (liver, muscle, bone) were carefully dissected and deep frozen. Before isotopic analysis, all samples were freeze-dried and powdered with mortar and pestle.

During sampling periods, large quantities of mucous macroaggregates were present in the water column. Hyperproduction of this mucilaginous material in the northern Adriatic has been known for more than 250 years and recently occurred during the summers of 1988, 1989, 1991, 1997 and this year. These macroaggregates are found in a variety of stages or forms - small flocs, macroflocs, stringers, tapes, clouds, creamy surface and gelatinous layers (Stachowitsch *et al.,* 1990). These mucous events were previously described by several authors (Degobbis *et al.,* 1995; Herndl, 1992; Mingazzini & Thake, 1995; Kovač *et al.,* 1998; Degobbis, 1999).

Analytical methods

Total particulate matter was determined gravimetrically. Organic carbon (POC) and total nitrogen (N) content of freeze-dried filters and sediment samples were determined after acid pretreatment with a commercial Carlo Erba 1108 elemental analyser.

The water content of the sediment was determined as a weight loss after drying at 80°C until constant weight (approximately 20-30 hrs).

Analyses of the ^{13}C and ^{15}N isotopic composition of freeze-dried samples were performed with a Europa 20-20 (Europa Scientific) mass spectrometer. Stable-isotope ratios were expressed in δ notation as parts per mill (‰) according to the following relationship:

$$\delta X = [(R_{sample}/R_{standard}) - 1] \times 10^3$$

where X is ^{13}C or ^{15}N and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Standards for ^{13}C and ^{15}N are V-PDB and atmospheric N_2 (air), respectively.

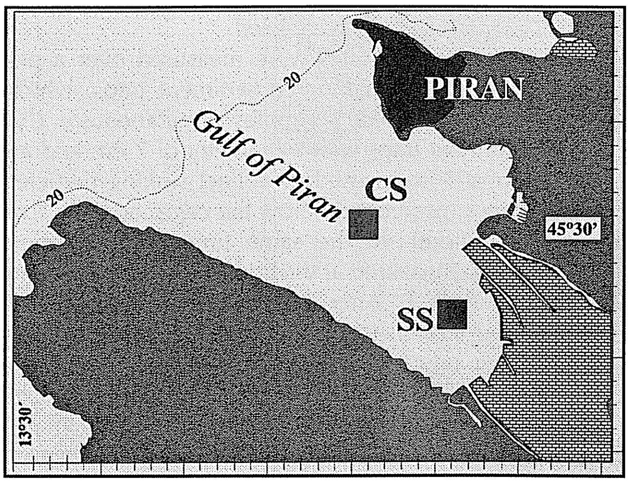

Fig. 2: Location of sampling (SS) and control (CS) stations in Piran Bay, Gulf of Trieste.
Sl. 2: Lokacija vzorčevalne (SS) in kontrolne (CS) postaje v Piranskem zalivu (Tržaški zaliv).

After extraction from the sediment in inert atmosphere, pore waters (0-2 cm depth in sediment, at each sampling point) were used to determine pH and concentration of hydrogen sulphide (H_2S) and total carbon dioxide (CO_2) (Grasshoff, 1983). Concentration of sulphate (SO_4^{2-}) was determined turbidimetrically (Tabatabai, 1974).

Surficial sediment (0-5 cm) containing meiofauna was taken using a core sampler, always with three replicates. Meiofauna was extracted from fixed surficial samples (5% formalin) by sieving and decantation (Wieser, 1960), identified as to major taxa and counted.

RESULTS AND DISCUSSION

Composition and sedimentation of suspended particulate matter

Differences in the composition of sedimented particulate matter from sampling (SS) and control (CS) sites are presented in Table 1. During the investigation period, the composition of particulate matter was affected by presence of macroaggregates with high content of carbohydrates and high atomic C/N ratio of 14.7 (mean value of macroaggregates sampled in June 2000). Nevertheless, based on the elemental analyses of the material collected during 24 hours in a trap placed under the fish cages the portion of organic carbon and total nitrogen was higher than that measured at the control site. The particulate matter originating from fish farm was enriched for 43% with organic carbon and about 66% with nitrogen. The higher input of proteinaceous material (organic waste originating in uneaten fish food) was in that case evident also from the lower C/N ratio (7.28, at.) in the sediment trap samples from the sampling station.

Tab. 1: Analyses performed in the sedimented particulate matter at sampling (SS) and control (CS) sites.
Tab. 1: Analize sedimentirane suspendirane snovi vzorčevalne (SS) in kontrolne (CS) postaje.

PARAMETER	**SEDIMENT TRAP SAMPLES (mean values)**	
	Sampling site (SS)	*Control site (CS)*
Content of organic carbon (%)	5.50	3.13
Content of total nitrogen (%)	0.90	0.35
C/N ratio (atomic)	7.28	10.60
Sedimentation ratio of total suspended matter ($g\ m^{-2}d^{-1}$)	73.19	36.16
Sedimentation ratio of total particulate nitrogen ($g\ m^{-2}d^{-1}$)	0.58	0.13
Sedimentation ratio of particulate organic carbon ($g\ m^{-2}d^{-1}$)	3.57	1.19

The comparison of measured sedimentation rates showed higher values in fish farm area. At the control site (CS), sedimentation rates of total suspended matter, particulate organic carbon and total particulate nitrogen were 36.16 g $m^{-2}d^{-1}$, 1.19 g $m^{-2}d^{-1}$ and 0.13 g $m^{-2}d^{-1}$. These sedimentation rates from the control station were similar to the rates previously reported for the unimpacted area of the Gulf of Trieste (Faganeli, 1989; Faganeli *et al.*, 1995). Sedimentation rates of total suspended matter, particulate organic carbon and total particulate nitrogen were about 51%, 67% and 78% higher under the fish cages and amounted 73.19 g $m^{-2}d^{-1}$, 3.5 g $m^{-2}d^{-1}$ and 0.58 g $m^{-2}d^{-1}$ respectively. Measured sedimentation rates showed higher input of organic matter below the cages. However, the measured sedimentation with mean carbon flux = 3.57 g $m^{-2}d^{-1}$ measured in our fish farm area was approximately 50% lower than the level of organic matter reported elsewhere (Angel *et al.*, 1992).

^{13}C and ^{15}N isotopic composition

The stable carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotope analyses were used to investigate the sources of sedimentary matter and to provide basic information about trophic relationships within the fish farm area. The mean values of terrigenous POM from the riverine inputs (-28.0‰), marine (-21.0‰) POM and net-zooplankton (-20.9 ‰ from the Gulf of Trieste (northern Adriatic) were previously reported by Faganeli *et al.* (1988). The mucous macroaggregates, which appeared in the Gulf of Trieste in summer 1997, were characterized by $\delta^{15}N$ value of 7‰ and $\delta^{13}C$ value of -19‰, which is typical of the phytoplankton of the Gulf of Trieste (Faganeli *et al.*, 1995). Additional average $\delta^{13}C$ and $\delta^{15}N$ values and elemental composition for selected components at sampling *(SS)* and control *(CS)* sites were measured (Tab. 2). The average $\delta^{13}C$ and $\delta^{15}N$ data obtained for different tissues of fishes varied between -20.52 and -24.66‰ and between 10.27 to 13.21‰. The highest $\delta^{13}C$ was found in fish muscle, followed by fish bone and fish liver. In the natural environment, sea bass *(Dicentrarchus labrax)* feeds on other fish and crustacea, but in the fish farm they are fed with artificial food. The values of $\delta^{13}C$ and $\delta^{15}N$ of fish were similar to those in dry food pellets fed to sea bass indicating their primary source of food. Unfortunately, fish tissue was not enriched in the $\delta^{13}C$ sufficiently over other measured components (with only slightly different values), suggesting that this parameter is not very suitable for the study of trophic relationships in this case. $\delta^{15}N$ values seem to be more appropriate but in any case some additional data of isotopic composition of other components are needed.

However, the $\delta^{13}C$ and $\delta^{15}N$ values of trap samples from the sampling site (-20.90‰ and 8.37‰) were more positive than those of samples from control site (-21.94‰ and 6.88‰), the former most probably reflecting the presence of waste products from fish farming. When the average $\delta^{13}C$ and $\delta^{15}N$ values obtained for surficial sediments under the fish cages were compared, we did not find significant differences between the sampling (-21.42‰, 3.93‰) and control sites (-21.58‰, 4.40‰).

Tab. 2: Average $\delta^{13}C$ and $\delta^{15}N$ values and elemental composition for selected components at sampling (SS) and control (CS) sites.

Tab. 2: Povprečne $\delta^{13}C$ in $\delta^{15}N$ vrednosti in elementna sestava izbranih sestavin iz vzorčevalne (SS) in kontrolne (CS) postaje.

SAMPLE	$\delta^{13}C_{PDB}$ (‰)	$\delta^{15}N_{air}$ (‰)	C_{org} (%)	N (%)	C/N (atomic)
Food for juvenile fish	-20.13	11.24	45.63	8.99	5.92
Food for adult fish	-22.22	9.08	42.79	7.39	6.75
Fish liver	-24.66	13.21	/	/	/
Fish muscle	-20.52	11.42	47.04	12.92	4.24
Fish bone	-23.46	10.27	/	/	/
Net-cage fouling	-21.41	5.50	10.01	1.78	7.10
Sediment trap samples *(SS)*	-20.90	8.37	5.50	0.90	7.28
Sediment trap samples *(CS)*	-21.94	6.88	3.13	0.35	10.43
Sediment *(SS)*	-21.42	3.93	1.11	0.12	10.43
Sediment *(CS)*	-21.58	4.40	1.26	0.13	11.04

Benthic impact of fish farming

Organic matter accumulates in surficial sediment under cage due to direct sedimentation of particulate matter as waste food, feces, unconsumed fish food pellets and enhanced sedimentation of fine particulate matter from the water column through flocculation (Hargrave *et al.*, 1997), furthermore adsorption on mucous macroaggregates. In order to assess the horizontal extent of the impact, surficial sediment samples were taken under the sea bass cage *i.e.* directly below the cage (SS1), beneath the edge of cage (SS2: 6 m from the centre of cage) and 6 m from the cage edge (SS3) as well as at the control site (CS) (Fig. 3) and analysed (Tab. 3).

Organic carbon and total nitrogen content in the surficial sediments at the station under the fish cages show some variations but the range of values under cages were similar to that at control site (see Tab. 3). Samples of dry food pellets fed to fish during the sampling time contained 42.79% C and 7.38% N by weight (C/N atomic ratio of 6.75). Even though no input of wastes from the fish farm occurred at the control station, the C/N ratio was only slightly higher. The atomic ratio

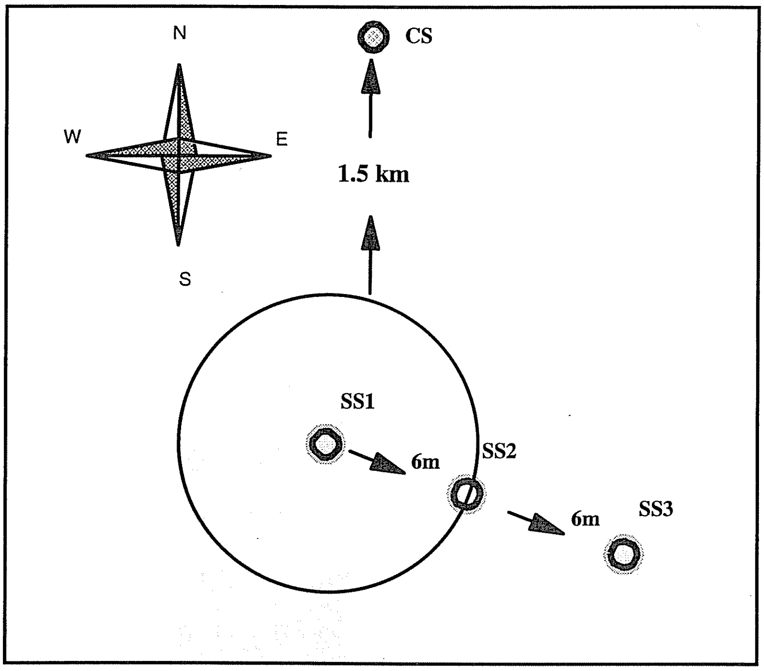

Fig. 3: Location of sampling points (SS1, SS2, SS3) in sediment under the fish farm and at control site (CS).
Fig. 3: Lokacije vzorčevalnih točk sedimenta na vzorčevalni (SS1, SS2, SS3) in kontrolni (CS) postaji.

Tab. 3: Parameters measured in sediment at the three sampling points (SS1, SS2, SS3) located under the fish farm and one point (CS) at control site.
Tab. 3: Analize sedimenta treh vzorčevalnih točk (SS1, SS2, SS3), lociranih pod gojiščem rib in na kontrolni postaji (CS).

PARAMETER	SEDIMENT			
	Sampling site (SS)			*Control site (CS)*
	SS1	*SS2*	*SS3*	*CS*
Water content (%)	51.26	57.02	56.68	66.46
N (%)	0.14	0.16	0.08	0.13
$C_{org.}$ (%)	1.19	1.44	0.70	1.26
C/N (at.)	9.87	10.77	10.77	11.04
$\delta^{13}C_{PDB}$ (‰)	-21.87	-21.32	-21.53	-21.58
$\delta^{15}N_{air}$ (‰)	3.8	3.8	4.2	4.4

Tab. 4: Concentrations of sulphate, hydrogen sulphide, total CO_2 and pH values measured in sediment (SS1, SS2, SS3) under the fish farm and at control site (CS).

Tab. 4: Koncentracije sulfata, vodikovega sulfida, celotnega CO_2 in pH vrednosti izmerjene v pornih vodah sedimenta (SS1, SS2, SS3) pod ribjimi kletkami in na kontrolni postaji (CS).

PARAMETER	SEDIMENT PORE WATER			
	Sampling site (SS)			*Control site (CS)*
	SS1	*SS2*	*SS3*	*CS*
SO_4^{2-}(mmol/L)	19.48	26.92	36.27	22.90
H_2S (μmol/L)	0.25	0.55	0.17	0.68
Total CO_2 (mmol/L)	2.93	4.40	4.55	2.80
pH	8.17	8.06	7.80	7.97

Tab. 5: Taxa and their mean abundances (No. ind./10 cm^2) determined at the three sampling points (SS1, SS2, SS3) in sediment under the fish farm and at control site (CS).

Tab. 5: Glavne skupine meiofaune in njihove srednje abundance (št. oseb./10 cm^2), določene na treh vzorčevalnih točkah (SS1, SS2, SS3) sedimenta pod ribjimi kletkami in na kontrolni postaji (CS).

	MEAN ABUNDANCES (No.ind./10 cm^2)			
TAXA	Sampling site *(SS)*			Control site *(CS)*
	SS1	*SS2*	*SS3*	*CS*
Nematoda	374.3	897	1180.3	1183.6
Harpacticoida	16	35.6	106	255.6
Polychaeta	32.3	34.3	48.3	125
Turbellaria	6.3	17.3	28.3	21.6
Gastropoda	0.6	0	1.3	5
Bivalvia	0	2	6	7
Kinorhyncha	0	0	0.6	22.3
Acarina	0	0	0	1.3
Hydroidea	0	0.3	2.3	1.6
Ostracoda	1.6	1.6	3.3	6.6
Ascidiacea	0	0	0	44.6
Amphipoda	0.3	0.6	0.3	0.6
Total	431	989	1377	1675

for organic carbon/nitrogen varied from 9.87 to 10.77 in sediment under the cages and at the control site was 11.04. Higher C/N ratio of organic matters in the surficial sediment of sampling site probably reflects the preferential degradation of N versus C or/and transportation of organic matter. These results suggest that the system could be in a quasi steady state, where removal processes balance the constant and enhanced organic matter loading from the cages.

Sediment water content in surficial sediment (0 to 2 cm layer) varied slightly (51.2% to 56.7%) with no consistent pattern in values between the sampling points under the fish farm. Higher sediment water content (Tab. 3) at the control station (66.4%) most likely reflects the finer grained texture of the sediment.

The results presented in Table 4 show low concentrations of dissolved H_2S in the intersticial water of the surficial sediment at all sampling points, almost at the limit of detection. Obviously all dissolved H_2S escapes out of the system. This is most probably due to the diffusion of H_2S out of the sediment and consequent oxidation in the water column. However, the low sulphate concentration and pH values above 8.1 below the centre of the fish cages might indicate H_2S precipitation in a form of pyrite as well (Ben-Yaakov, 1973).

Sulphate concentrations decrease from SS3 to SS1 indicating strong impact (similar to the results of meiofauna examination) directly under the centre of cages. Organic matter decomposition and consequently nutrient production in the surficial sediment is vice versa increasing in the opposite direction, with highest nutrient concentrations at SS3. Therefore it is obvious that the fish farming impact is spread over at least three times larger area then the cage settlement.

The meiofauna revealed differences in abundances and diversity with distance. A list of meiofauna taxa and their abundance at all sites is presented in Table 5. The densities of the total meiofauna were approximately 66% lower at SS1 point and 33% lower at the SS2 point than at the control site, but the difference was not evident for SS3 sample point.

In addition to lower abundances of both total meiofauna and their leading groups (Nematoda, Harpacticoida, Polycheta, Turbellaria) at the more impacted zone (SS1, SS2), we observed also absence of some typical meiofaunal groups (Gastropoda, Bivalvia, Kinorhyncha, Hyroidea). According to the data, the meiofauna from the control site reflects typical (normal) summer community of unimpacted area (Vrišer, 1997). The same variation in meiofauna could be due to differences in ecological factors (such as particle size distribution of sediment) at sampling and control sites.

Few particular studies regarding the fish farming impacts on benthic communities were found in the literature before 1999. Lower abundance and biomass (up to 37% of the normal community) of macrofauna at the fish cages sites are reported by Weston (1990) and Hargrave *et al.* (1997), though these results are presented in the context of the different methodological and/or ecological aspects. Our results (*i. e.* a 66% reduction of the total abundance and disappearance of some sensitive groups as Mollusca and Kinorhyncha) are highly consistent with the last published studies (Mazzola *et al.,* 1999, 2000; La Rosa *et al.,* 2000; Mirto *et al.,* 2000) on fish mariculture effects on meiofauna.

CONCLUSIONS

Environmental changes were most evident in benthos showing a long-term impact of fish farming on meiofauna communities. Settling of unconsumed food and constant deposition of waste and fish feces under and adjacent to fish cages has been found to reduce diversity and abundance of benthic meiofauna. The impact, *i.e.* impoverishment of meiofauna, was local and most pronounced in the sediment directly below the cages.

Pore water concentrations of hydrogen sulphide, sulphate and elemental composition of sediment also indicate the greatest impact directly under the cages. However, despite continuous organic loading on the sediments below the fish cages, the measured concentrations were within variability of the background levels of the Bay of Piran.

The sedimentation of total suspended matter, particulate organic carbon and total particulate nitrogen in the fish farm region was greater than that at the control station because of the higher deposition of organic waste in the form of feces and uneaten food beneath the fish farm. In comparison to the control site, the lower C/N ratio of sedimented suspended matter in the fish farm accounted 7.3 (at.), indicating a greater supply of proteinaceous material.

The values of $\delta^{13}C$ and $\delta^{15}N$ of fish were similar to those in dry food pellets fed to sea bass (*Dicentrarchus labrax)* indicating their primary source of food. The highest values of $\delta^{13}C$ and $\delta^{15}N$ were observed in the sediment trap samples resulting from heterogeneous sedimented material, such as particulate matter, waste food, feces and mucous macroaggregates.

Results of this preliminary study suggest that the system could be in a *quasi* steady state, where removal processes balance the organic matter loading from the cages. Several mechanisms could be responsible for this situation, including site-specific properties such as bottom currents, water exchange and bottom topography, rapid OM decomposition rates, sediment characteristics and bioturbation. Nevertheless, additional analyses concerning the impact on sediment, such as quantification of decomposition of organic matter by benthic flux chamber, observation of bacterial mats and determination of more detailed sediment profiles (biological and chemical parameters) under the fish farm, must be performed in the future.

The database from this study provides useful information for the better planning of future investigations of the fish farm impact and for reduction of the organic matter overload in the shallow coastal ecosystem of the northern Adriatic.

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VPLIVI GOJENJA RIB NA MEIOFAUNO TER BIOGEOKEMIČNE LASTNOSTI SEDIMENTA TRŽAŠKEGA ZALIVA

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POVZETEK

V območju marikulture se kopiči neporabljena hrana, potrebna za intenzivno gojenje morskih organizmov, presnovni produkti organizmov, kot so feces in različni eksekreti ter različni kemijski dodatki, kot so antibiotiki in protiobrastna zaščitna sredstva. Konstanten in povečan vnos organske snovi posledično vodi do sprememb ekoloških lastnosti obremenjenih območij te vrste, zato smo v okviru te študije opravili preliminarne raziskave območja marikulture rib v Piranskem zalivu.

Vzorčevanje je potekalo v okviru 24-urnega terenskega dela (21. in 22. junija 2000) na vzorčevalni postaji v območju gojišča rib ter na kontrolni postaji, locirani zunaj neposrednega vpliva marikulture. Preliminarni rezultati te študije so pokazali največje spremembe v bentoški združbi (spremembe v sestavi populacije meiofaune), ki so odsev dolgotrajnega vpliva marikulture. Osiromašnje meiofaune in višje koncentracije vodikovega sulfida v pornih vodah je bilo najbolj izraženo v sedimentu neposredno pod ribjimi kletkami. V območju gojišča rib smo zabeležili tudi višje vrednosti celotne suspendirane snovi, suspendiranega organskega ogljika in celotnega dušika, kar je verjetno posledica večjega vnosa organske snovi. Nižje vrednosti C/N razmerij suspendirane snovi vzorčevalne postaje pa potrjujejo večji vnos proteinske snovi (odpadne snovi gojenja rib) glede na kontrolno postajo. Izotopska sestava, tj. vrednosti $\delta^{13}C$ in $\delta^{15}N$ analiziranih gojenih rib, je bila podobna tistim, določenim v hranilnih peletih, s katerimi hranijo ribe, kar kaže, da so le-ti njihov primarni vir prehrane.

Rezultati te študije so podlaga in izhodišče za nadaljnje raziskave vplivov marikulture na obalno slovensko morje.

Ključne besede: ribje kletke, $\delta^{15}N$, $\delta^{13}C$, sedimentacijske pasti, sediment, meiofauna

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MEIOFAVNA IZOLSKE LUKE PRED GRADITVIJO MARINE IN PO NJEJ: PONOVLJENA RAZISKAVA - PRELIMINARNI REZULTATI

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IZVLEČEK

Članek obravnava strukturne in abundančne značilnosti meiofavne treh vzorčevalnih postaj na širšem področju Izolske luke pred graditvijo nove marine (leta 1991) in 8 let pozneje (1999). Preliminarni rezultati ponovljene raziskave za zdaj niso pokazali opaznih biocenotskih sprememb, vsaj ne na ravni glavnih taksonomskih skupin, ki bi jih utegnila povzročiti ekološka motnja sedimentacije skaljenega vodnega sloja med grobimi gradbenimi posegi v morsko okolje.

Ključne besede: meiofavna, Izolska luka, ponovljena raziskava

MEIOFAUNA DELL'AREA PORTUALE DI ISOLA PRIMA E DOPO LA COSTRUZIONE DELLA MARINA: STUDIO RIPETUTO - RISULTATI PRELIMINARI

SINTESI

L'articolo presenta le caratteristiche strutturali e quantitative della meiofauna in tre stazioni di campionamento nell'area portuale di Isola, prima della costruzione della nuova marina (1991) e 8 anni dopo (1999). Al momento i risultati preliminari dello studio ripetuto non hanno evidenziato cambiamenti di biocenosi, almeno non a livello dei maggiori gruppi tassonomici. Sembra che il maggiore fattore di disturbo ecologico, la sedimentazione del particolato sospeso, non sia stato abbastanza intenso da provocare cambiamenti rilevanti.

Parole chiave: meiofauna, area portuale di Isola, studio ripetuto

UVOD

Ob vrsti načrtnih raziskav meiofavne našega dela Tržaškega zaliva se je zlasti v zadnjih dveh desetletjih nabralo precej manjših preiskav meiofavne, deloma samostojne narave, večinoma pa kot sestavni del različno zastavljenih naročniških ekspertiz, strokovnih mnenj ali lokalnih študij. Ker je večina tovrstnih del vezana v glavnem na ugotavljanje obstoječega oz. zatečenega, t.i. "ničelnega" stanja pred večjimi posegi v morsko okolje (npr. graditvijo luk, marin ali marikultur), nam ponovitev takih vzorčevanj daje dragoceno priložnost ugotavljanja morebitnih biocenotskih sprememb okolja na osnovi časovnih primerjav.

Menimo, da je mogoče tudi s takšnimi, še neobjavljenimi, po obsegu in ciljih skromnejšimi študijami prispevati k boljšemu poznavanju našega obalnega pasu. Zato nameravamo s časovnimi ponovitvami starejših raziskav meiofavne nadaljevati tudi v prihodnje. Ponovljena raziskava Strunjanskega zaliva (Vrišer, 1999) nam je kot prva iz te serije lahko vzorčni primer tovrstnega pristopa.

Pričujoči prispevek podaja časovno primerjavo dveh enakih (iste lokacije, enaka metodika) kvalitativnih in kvantitativnih posnetkov stanja meiofavne s področja ožjega akvatorija in neposredne okolice Izolske luke iz obdobja pred graditvijo marine (1991) in osem let kasneje (1999).

EKOLOŠKE ZNAČILNOSTI IZOLSKEGA ZALIVA

Širše področje Izolske luke sestavlja polkrožen, proti zahodu odprt zaliv, ki ga s severa zapira stari luški valolom, nov velik valobran marine pa od severozahoda. Vso vzhodno in južno stran zaliva obdaja pretežno zidana pristaniška obala z zaledjem turističnih in industrijskih objektov.

Morsko dno v področju stare luke (Sl. 1, postaja A) je fini ilni mulj sulfidnega značaja, črne barve, s tankim aerobnim površinskim slojem (1 cm, sivorjave barve). Na lokacijah B (vhod v današnjo marino) in C (zunaj luke in marine) prevladuje ilni mulj nesulfidnega značaja (siva glina) z debelejšim (2-3 cm) aerobnim površinskim slojem in primesjo finega peska.

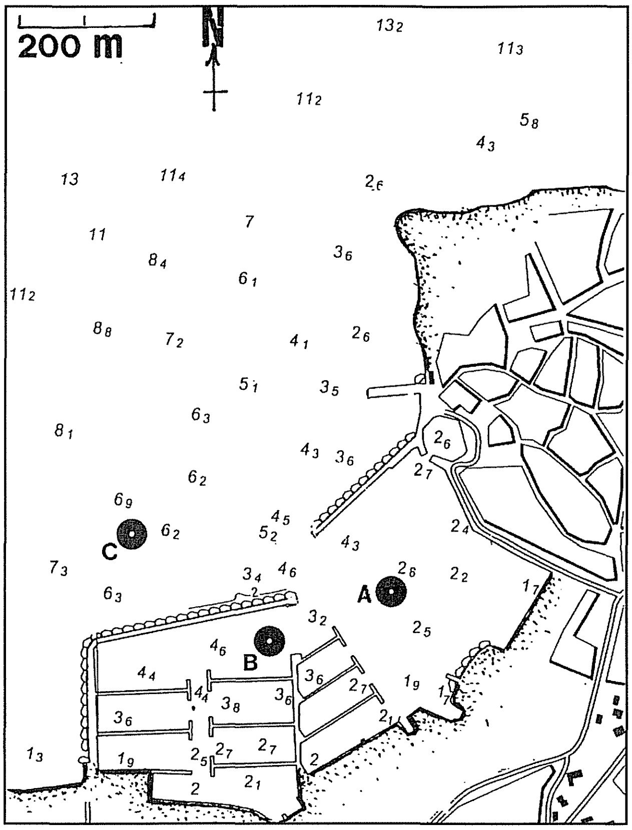
Makrobentoško združbo tega območja je raziskava 1981 leta (Vrišer *et al.*, 1981) v floristično - favnističnem smislu razdelila v tri cone:

1) Zaradi dolgoletnega onesnaženja, pretežno organskega izvora (kanalizacija in odpadki predelovalne industrije), je ta močno degradirana cona obsegala področje stare luke (lokacija A) s prevladujočo morsko solato *Ulva rigida*. Favna te združbe je bila nizke diverzitete z maloštevilnimi, 15 vrstami. Še največ je bilo polihetnih črvov in školjk, a od slednjih le ene same vrste.

2) V coni prehodnega pasu (postaja B) smo sicer še našli manjše količine morske solate, prav tako brez morskih trav, kot v bolj onesnaženi coni, a s favno precej višjega števila, 20 vrst.

3) Tretjo cono (njen zunanji del ponazarja postaja C) na že bolj peščenem sedimentu so ob obali naseljevali redki sestoji morskih trav *Cymodocea nodosa*, številne školjke in poliheti, skupno 38 vrst makrobentoških rastlin in živali. Po skromnejši rasti trav in hkratnemu uspevanju ulve pa lahko sklepamo, da je bil tudi ta pas leta 1981 še vedno pod vplivom onesnaženja.

V obdobju po letu 1981 je bilo v celoti sanirano onesnaževanje Izolske luke, vendar pa je v zadnjem desetletju v njenem zahodnem delu zrasla obsežna marina (Sl. 1).



Sl. 1: Raziskovano območje z vzorčevalnimi postajami.
Fig. 1: Research area with sampling stations.

MATERIAL IN METODE

Vzorce meiofavne smo na področju Izolske luke odvzeli 27. 11. 1991 in 25. 11. 1999 na 3 postajah: A, B in C (Sl. 1) in jih nato laboratorijsko obdelali po standardnih metodah ekstrakcije (sejanje z izpiranjem) in separacije. Površinski sediment smo odvzeli z gravitacijsko sondo (Meischner & Rumohr, 1974) s pomočjo cevnega korerja (premer odprtine 3,5 cm) 5 cm globoko. Meiofavno smo ekstrahirali iz konserviranih vzorcev (5% formalin v morski vodi) s sejanjem (velikost mrežic 0,050 µm-1 mm) in dekantacijo po Wieserju (1960). Makrobentoški vzorci so bili odvzeti z grabilom Van Veen (0,1 m²), presejani skozi sita (2 mm) in shranjeni v 4% formalinu.

REZULTATI

Meiofavno raziskovanih treh postaj, njeno sestavo in abundanco v letih 1991 in 1999 podajamo v tabeli 1.

Analiza meiobentosa na postajah A, B in C je leta 1991 pokazala mešane značilnosti tako čistega kot tudi onesnaženega okolja, poznanega iz primerljivih študij stresnega okolja naše obale. Slednje velja zlasti za lokacijo A, ki je pokazala znake dolgotrajnih evtrofnih učinkov pretežno organskega onesnaženja industrijskega izvora. To se kaže v zvišani gostoti harpaktikoidnih kopepodov *(Harpacticoida)*, ki naraščajo v smeri proti notranjosti Izolske luke, medtem ko številnost bentoških polihetnih črvov *(Polychaeta)* v tej smeri enakomerno upada.

Po drugi strani pa je bila abundanca med meiofavno prevladujoče, dominantne skupine *Nematoda* in njena razporeditev na vseh treh raziskovanih postajah bolj značilna za neobremenjeno, čisto okolje.

Ponovitev raziskave v letu 1999 (Tab. 1) je proti pričakovanju pokazala skoraj enake strukturne in kvantitativne vrednosti kot pred osmimi leti. Presenečajo zlasti abundance, razlike so celo manjše od pričakovanih naravnih oscilacij.

RAZPRAVA

Posegi v morsko okolje, velikostnega ranga postavitve velikih luških valobranov kot v našem primeru, so za meiobentoško favno obremenitev, ki jo lahko opredelimo kot najmanj dvojno ekološko motnjo. Na samem kraju in v neposredni bližini podvodnih nasutij oz. deponij gradbenega kamenja prihaja do odplavljanja in mešanja flokulentnih vrhnih slojev sedimenta in meiofavne v vodni stolpec (resuspenzija). V širši okolici nasutij, do nekaj sto metrov oddaljenosti, naša vzorčevanja so bila vsa znotraj te cone, pa ekološko motnjo povzroča posedanje (sedimentacija) finejših sestavin z vodo pomešanega anorganskega sedimenta in organskega detrita ter frakcij pasivnejše, manj vagilne meiofavne na morsko dno. Ekološka motnja sedimentacije je bila na raziskovanem območju opazna le v nekajmesečni fazi grobih gradbenih del, pozneje pa le še občasno. Točnejših podatkov sedimentacije nimamo in bi jih lahko dale le kontinuirane specializirane terenske meritve.

O vplivu ekoloških motenj najrazličnejših vrst na meiobentos obstaja v strokovni literaturi sicer pisana zbirka številnih študij, ki pa v veliki večini obravnavajo specifične vidike zelo ozko definiranih okvirov eksperimentalnega pristopa, tematsko slabo uporabnih za primerjavo z našimi opažanji.

Tako se lahko npr. motnja razkopavanja in mešanja sedimenta z vodnim slojem negativno odraža v meiofavni le kratkoročno in se nato združba običajno nor-

Tab. 1: Struktura in abundanca (št. os. /10 cm², paralelke a, b, c in srednja vrednost) meiofavne na postajah A, B in C v letih 1991 in 1999.
Tab. 1: Meiofaunal community structure and abundance (No. ind. /10 cm², replicates a, b and c, and mean value) at stations A, B and C in 1991 and 1999.

	postaja / station A				postaja / station B				postaja / station C			
	a	b	c	**sred. vred. / mean**	a	b	c	**sred. vred. / mean**	a	b	c	**sred. vred. / mean**
1991												
Nematoda	384	480	836	**566,6**	732	488	1300	**840,0**	532	500	472	**501,3**
Harpacticoida	148	168	240	**185,3**	48	164	104	**105,3**	60	112	88	**86,6**
Polychaeta	8	8	20	**12,0**	28	4	8	**13,3**	12	28	40	**26,6**
Oligochaeta	12	8	12	**10,6**	16	28	28	**24,0**	20	4	12	**12,0**
Turbellaria	8		8	**5,3**		16	20	**12,0**		12	4	**5,3**
Bivalvia											4	**1,3**
Hydroidea		4		**1,3**								
1999												
Nematoda	448	506	816	**590,0**	473	1241	747	**808,0**	483	490	496	**489,6**
Harpacticoida	179	137	242	**186,0**	177	36	101	**104,6**	92	108	54	**84,6**
Polychaeta	10	14	12	**12,0**	8	32	4	**14,6**	41	27	18	**28,6**
Oligochaeta	6	6	17	**9,6**	10	19	30	**19,6**	14	6	19	**13,0**
Turbellaria	2	6	7	**5**	7	21	3	**10,3**	7	7	6	**6,6**
Bivalvia										1	3	**1,6**
Ostracoda							1	**0,3**			1	**0,3**
Kinorhyncha									1			**0,3**

malizira (v primeru, da ni močnih tokov) že po nekaj dneh (Fegley, 1987; Sherman & Coull, 1980). Vplivi sedimentacije so nasploh lahko precej raznovrstni. Vse od možnosti prostorsko mozaično strukturiranega povečanja produktivnosti posameznih skupin meiofavne (Grassle & Sanders, 1973; Johnson, 1970), najverjetneje zaradi zmanjšanja tekmovalnosti (o tem obstoji vrsta delovnih hipotez), pa do očitnega nazadovanja združb v primerih močne lokalne sedimentacije (Rhoads *et al.*, 1978). Primeri zadnje so najizrazitejši v tistih luških akvatorijih, ki so pod stalnim vplivom vzdrževalnih del (dredžanja, vzdrževalna poglabljanja plovnih poti), kot je to opaziti s skromno meiofavno tudi na ožjem območju luke Koper.

Ocenjujemo, da je bila ekspozicija sedimentacijske obremenitve v našem primeru verjetno prekratka ali pa prešibka, da bi pustila vidne posledice na ravni gostote glavnih skupin meiofavne, morebitne spremembe znotraj ustroja dominantnih skupin (npr. Harpacticoida) pa bodo še predmet nadaljnjih analiz.

Gledano v celoti, lahko na osnovi obeh pregledov (1991, 1999) ugotovimo, da je srednja abundanca meiofavne raziskovanega območja sicer višja, kot je običajno v primerljivih razmerah onesnaženega okolja, a vendarle nižja kot v čistem okolju. V raziskovani meiofavni nasploh ni opaziti bistvenih posebnosti, le lokacija A v notranjosti luke izkazuje nekatere poteze zmerno onesnaženega okolja.

Ponovljena raziskava je v mejah uporabljenih metod pokazala, da se gradbeni posegi (valolom, pomoli, preureditev obalne črte) niso neposredno pokazali na obstoječi združbi meiofavne. Ugotavljamo, da saniranje onesnaženja v stari Izolski luki v smeri izboljšanja ekoloških razmer, a po drugi strani povečana stagnantnost z marino ograjenega akvatorija v smeri potencialnega poslabšanja stanja za zdaj v opazovanem časovnem razponu niso povzročili v meiobentosu raziskovanega področja opaznih sprememb.

Zaradi zadnjih, novih dodatnih gradbenih posegov v ta morski prostor in še manjkajočih taksonomskih preiskav bomo z vzorčevanji nadaljevali in v tem smislu predstavljene rezultate opredeljujemo kot preliminarne.

MEIOFAUNA OF THE IZOLA HARBOUR AREA 8 YEARS AFTER THE NEW MARINA WAS COMPLETED: A REPEATED INVESTIGATION - PRELIMINARY RESULTS

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SUMMARY

To establish potential changes in meiofaunal community, a sampling in the Izola harbour area (Gulf of Trieste, Northern Adriatic) was repeated 8 years (November 1991, November 1999) after the large new marina was completed.

Recent, still preliminary results show almost identical structural and quantitative characteristics of the meiofauna as in the year 1991. It seems that in our case the main ecological disturbance - the sedimentation of suspended sediment, well known from the literature - was not long (or intensive) enough to cause visible changes on the level of main meiofaunal groups. More detailed taxonomic analyses on harpacticoid copepods (Harpacticoida, Copepoda) of the area will follow.

Key words: meiofauna, Port of Izola, repeated investigation

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ELEONORA'S FALCON *(FALCO ELEONORAE,* GENE 1839) IN CROATIA: RANGE, THREATS AND THE PROPOSAL OF ACTION AND MANAGEMENT PLAN

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ABSTRACT

Eleonora's Falcon is classified as rare in Europe. This species is also included in the first group of priorities for the protection of biological diversity by the Ministry of Environment and Physical Planning of the Republic of Croatia. Croatian population of Eleonora's Falcon has not been sufficiently researched and its nest sites have not been protected so far. We have been investigating Eleonora's Falcon population in Croatia for three years. The research consisted of two main parts - study of the breeding ecology of colony F3 and census of the entire Croatian population. The population was estimated at 58-68 breeding pairs in six colonies and we made a proposal as to the action and management plan for this species in Croatia.

Key words: *Falco eleonorae,* Eleonora's Falcon, Croatia, action plan, management plan

FALCO DELLA REGINA (*FALCO ELEONORAE* GENE 1839) IN CROAZIA: DISTRIBUZIONE, PERICOLI E PROPOSTA DEL PIANO DI AZIONE E GESTIONE

SINTESI

Il Falco della Regina in Europa è classificato come specie rara. Il suo nome è stato inserito nel primo gruppo delle priorità per la tutela della diversità biologica dal Ministero per l'ambiente della Repubblica di Croazia. La popolazione del Falco della Regina in Croazia non è stata studiata a sufficienza e i suoi siti di nidificazione non vengono ancora tutelati. Da tre anni gli autori studiano la popolazione del Falco della Regina in Croazia. La ricerca comprende lo studio delle modalità di riproduzione della colonia F3 nonché il censimento dell'intera popolazione. Si stima che questa comprenda 58-68 coppie in sei colonie. Gli autori hanno ultimato la proposta per il piano di azione e gestione di questa specie in Croazia.

Parole chiave: *Falco eleonorae,* Falco della Regina, Croazia, piano di azione, piano di gestione

INTRODUCTION

Eleonora's Falcon (*Falco eleonorae*, Gene 1839) breeds mostly in the Mediterranean region. The total population of this species, which is classified as rare at the European level (Tucker & Heath, 1994), is estimated at some 6320 pairs (Ristow, *in print)*. The species is also included in the first group of priorities for the protection of biological diversity by the Ministry of Environment and Physical Planning of the Republic of Croatia (Državna uprava za zaštitu prirode i okoliša, 1999). The Croatian population of Eleonora's Falcon has not been sufficiently researched enough and most of the data are based on accidental and occasional observations (Jovanović, 1972; Krpan, 1965, 1980; Lukač *et al.*, 1997).

It's nest sites have not been protected so far.

MATERIAL AND METHODS

We have been studying the population of Eleonora's Falcon in Croatia for three years - 1998, 1999 and 2000 (Tab. 1). The research consisted of two main parts - study of the bird's breeding ecology in colony F3 and census of its total Croatian population.

Tab. 1: Years, locations and dates of the carried out fieldwork.
Tab. 1: Leta, lokacije in datumi terenskega dela.

YEAR	LOCATION	DATE
1998	Colony F3	July 25-30 September 10-11
1999	Colony F3	August 03-08 September 13
2000	Colony F3	August 07-13 September 12-21
	Islands of the Central and South Adriatic (census)	August 19-31

The codes of the colonies are according to Walter (1978). During the research, the birds were observed by binoculars BPC 7x50 and BPC4 8x30 and the telescope Opticron HR66 45R from boat cruising along the cliffs and, in some cases, from various islands. During observations from the boat, birds were startled by a special siren in order to make them fly away from their nest sites and thus to enable us to make all the necessary records.

The census was made with the aid of eleven metres long sailing ship and a small boat at the following Central and South Adriatic islands: Dugi otok, Kornati Isles, Jabuka, Kamik, Svetac, Biševo, Vis, Greben, Sušac, Bijelac, Lastovo, Korčula, Mljet and Elafiti Isles. The 1997 data from Palagruža are also included in the census.

Foreign experience and recommendations (Ristow, in print) were used, too.

RESULTS

Population of Eleonora's Falcon in Croatia

During the first census of Eleonora's Falcon in Croatia, six colonies were registered (Tab. 2).

Tab. 2: Colonies and a number of breeding pairs estimated during the 2000 census.
Tab. 2: Kolonije in število gnezdečih parov, ugotovljenih med štetjem leta 2000.

COLONY	NUMBER OF PAIRS
F2	6-8
F3	38-42
F4	2
F6	3-4
F7	5-7
F8	4-5

The colonies are situated on five Central Dalmatian islands and defined according to Walter (1979) and Ristow *et al.* (1989).

The area of distribution

Island A covers 4.6 square kilometres. It is temporarily inhabited, with a low level of agriculture, mostly vineyards and Mediterranean vegetation, predominantly maquis and pine forests.

Island B covers 0.08 square kilometres, it is uninhabited and with very poor vegetation. These two islands are the sites of colony F3.

Fig. 1: Eleonora's falcon** (Falco eleonorae). **(Photo: D. Ristow)
Sl. 1: Sredozemski sokol** (Falco eleonorae). **(Foto: D. Ristow)

Island C covers 90.3 square kilometres and is inhabited, with various activities practised there, such as tourism, agriculture, hunting, traffic and fishing. Colonies F2 and F6 are situated on this island.

Island D is 5.8 square kilometres large with several permanent inhabitants and a low level of agriculture. During the summer there are some tourist activities practised on this island and around it. Colonies F7 and F8 are situated on this island.

Island E is 0.4 square kilometres large, uninhabited and with some low vegetation. Colony F4 is situated on it.

DISCUSSION

Potential threats and limiting factors

Natural factors

Nests of the Eleonora's Falcon could be naturally endangered by various predators, such as snakes, ravens, gulls or some raptor species. Adult falcons are able to defend their nests, and the predators mentioned above should thus not threaten the population. Some parasites and diseases, such as Mallophaga, *Haemaphysalis hoody* and a form of malaria, were also registered in some colonies (Ristow & Wink, 1985), but they do not essentially affect the size of the colonies.

Introduction of allochtonous species to the islands with Eleonora's Falcon colonies

Over 90% of the Croatian population breeds on large inhabited or temporarily inhabited islands. Various predators or other allochtonous species (cats, dogs, rabbits, rats, sheep and so on) were colonized on those islands long ago, and it is likely that their density on some islands has declined due to the depopulation.

Hunting and illegal trade

In the past, the locals were known to eat the nestlings, but this custom has practically disappeared. There is some possibility of an occasional, accidental poaching, and this species could also be interesting for egg collectors due to its rarity. Eleonora's Falcon is not interesting for falconry purposes.

Pressures on the bird's nest sites

Intensive urbanization and sea traffic close to the colonies could be very detrimental for the breeding birds. During the parents' absence, the eggs or young could be attacked by predators, and embryos in eggs could be destroyed due to overheating, if eggs are directly exposed to the sun.

Fig. 2: Nestling of the Eleonora's falcon. (Photo: G. Piasevoli)
Sl. 2: Mladič sredozemskega sokola. (Foto: G. Piasevoli)

Habitat degradation

Disappearance of natural vegetation and intensive agriculture could reduce the food sources for falcons. Forest fires could be a potential cause of disappearance of natural vegetation. Drinking water is also important for the bird's colonies. Small pools, the only reserves of drinking water for falcons, are not maintained nowadays and are rapidly disappearing due to depopulation and decreasing agriculture.

Poisoning

Irresponsible usage of agricultural chemical agents could cause poisoning. This, however, has not been registered in Croatia so far, but it has certainly been recorded in some other countries (Ristow, 2001) and could thus be expected here as well.

Aims and proposed actions

Trends and oscillations regarding the size of the population are completely unknown due to the insufficient research so far. It is necessary, however, that at least the Falcon's present numbers are retained through protection.

The following measures should be undertaken:

1. *Legal aspect*

1. 1. To declare protection of all nest sites by the Nature Protection Law as special reserves or nature monuments and to include them in large marine and pelagic islands as a protected and sustainably managed area;

1. 2. to prevent eventual nest plundering with certain

protection measures in every reserve or nature monument;
1\. 3. not to allow hunting activities in the hinterland of the colonies before November 1st;
1\. 4. to authorize persons to monitor and guard the colonies, *i.e.* to immediate intervene and prevent people breaking the law;
1\. 5. to include the protection of the colonies in the complete regional and national strategy of the coastal zone development.

2. Economic activities development policy
2\. 1. To protect colonies from various pressures caused by too heavy traffic of tourist ships and aircraft; to stimulate development of sustainable, ecological tourism, whose main resource should be well preserved nature; to prevent any extensive building of new tourist accommodation capacities and other structures on the low urbanized small islands with the Falcon's colonies, especially close to them;
2\. 2. to stimulate organic agriculture on the islands, with minimal use of pesticides and herbicides.

3. International cooperation
3\. 1. To ensure a coordination of the national action plan with the adequate plans at the international level.

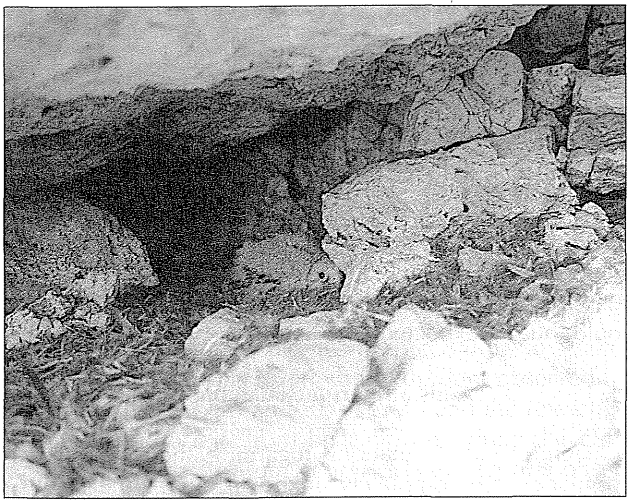

Fig. 3: Nest of the Eleonora's falcon with huge remains of feathers of preys in front of it. (Photo: G. Piasevoli)
Sl. 3: Gnezdo sredozemskega sokola z lepo vidnimi ostanki perja različnih vrst njegovega plena. (Foto: G. Piasevoli)

4. Habitat protection
4\. 1. To ensure natural succession of vegetation in the large parts of the islands, which are known as the Falcon's hunting grounds. Forrest management should be under control by nature conservation institutions;
4\. 2. to ensure continuos maintenance of small water habitats, in order to prevent them from drying up during the summer;
4\. 3. to prevent introduction of allochthonous species to the small islands.

5. Research and monitoring
5\. 1. To carry out a census of the entire population every year;
5\. 2. to carry out a detailed research in one colony. Research should include counting of eggs and chicks, establishing the breeding success, taking samples of blood and food remains, measuring the eggs, bird ringing and other methods of marking (including satellite tracking), registering the losses in the colony and reasons for them, and observation of any other parameters of the breeding ecology;
5\. 3. To observe any eventual changes in all colonies, by temporary short surveys and to react if necessary;
5\. 4. to ensure financial and technical conditions for the planned research and monitoring.

6. Public awareness raising
6\. 1. To raise the awareness - especially of the locals, young people and boat owners - of the need to protect the Eleonora's Falcon,
6\. 2. to raise the awareness that preserved nature is a potentially important economic, primarily tourist, resource;
6\. 3. to prepare printed and other materials in Croatian and foreign languages;
6\. 4. to cooperate with NGOs;
6\. 5. to set up tourist information centres for the natural riches of pelagic islands and marine ecosystems;
6\. 6. to cooperate with the maritime police and to train their officers.

Proposed implementers and the duration of the plan

This plan should be implemented by the Ministry of Environment and Physical Planning of the Republic of Croatia and the Public Institution for the Management of Protected Areas in the County of Split and Dalmatia. It should be continual.

CONCLUSIONS

Eleonora's Falcon is classified as a rare species in Europe and, during the first census, the Croatian population was estimated at 58-68 breeding pairs. This is the reason why this species can be considered as potentially endangered in Croatia. Therefore, it is necessary to make an action and management plan for its population in Croatia.

The plan is based on the data collected so far. It consists of the data on the number of birds and colonies, potential threats and limiting factors as well as aims with proposed actions.

ACKNOWLEDGEMENTS

We would like to thank Dr Dietrich Ristow for his friendly and selfless suggestions, advice and help during our work.

SREDOZEMSKI SOKOL (*FALCO ELEONORAE*, GENE 1839) NA HRVAŠKEM: NJEGOVA RAZŠIRJENOST, OGROŽENOST IN PREDLOG ZA AKCIJSKI NAČRT IN NAČRT UPRAVLJANJA

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POVZETEK

Sredozemski sokol je opredeljen kot redka evropska ptica in vključen v prvo skupino prioritet v ohranjanju biotske raznovrstnosti, kot jih navaja hrvaško Ministrstvo za okolje in prostor. Hrvaška populacija sredozemskega sokola še ni bila ustrezno raziskana in tudi gnezdišča te ujede še niso zaščitena. Glede na to, da je ta vrsta redka in zatorej potencialno ogrožena, je bilo treba pripraviti ustrezen akcijski načrt in načrt upravljanja.

Populacijo sredozemskega sokola na Hrvaškem smo raziskovali tri leta, in sicer v sklopu preučevanja njegove gnezditvene ekologije v koloniji F3 in štetja celotne hrvaške populacije. Potem ko je bilo ocenjeno, da v šestih kolonijah gnezdi od 58 do 68 parov, je bil pripravljen osnutek akcijskega načrta in načrta upravljanja za to vrsto na Hrvaškem.

Potencialne nevarnosti za hrvaško populacijo sredozemskega sokola so naravni dejavniki, naseljevanje alohtonih vrst na otoke, kjer gnezdi ta ptica, lov in nelegalna trgovina, posegi v prostor s sokolovimi gnezdišči, degradacija habitata in zastrupljanje narave. Glavni namen načrta je ohraniti vsaj današnjo populacijo sredozemskega sokola, kar naj bi dosegli s pripravo in uresničevanjem zakonskih predpisov, nadzorom nad gospodarskimi dejavnostmi, mednarodnim sodelovanjem, zaščito habitata, raziskovalnimi dejavnostmi, spremljanjem stanja (monitoringom) in z ozaveščanjem javnosti.

Ključne besede: *Falco eleonorae*, sredozemski sokol, Hrvaška, akcijski načrt, načrt upravljanja

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ZAVAROVANA OBMOČJA KOT ORODJE ZA OHRANJANJE BIODIVERZITETE V SREDOZEMLJU

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IZVLEČEK

Glede na izgubo mokrišč v sredozemskih državah v zadnjih nekaj desetletjih in zaradi vse večjih zahtev turizma in drugih prostorskih načrtovanj v teh državah postaja jasno, da biodiverzitete v Sredozemlju, posebno na mokriščih in obalnih območjih, ne bo mogoče ohraniti zgolj s sonaravno uporabo virov. Avtor opozarja, da so zavarovana območja eno najučinkovitejših sredstev za ohranjanje biodiverzitete in situ.

Ključne besede: zavarovana območja, biodiverziteta, varstvo narave, Sredozemlje

LE AREE PROTETTE COME STRUMENTO PER LA CONSERVAZIONE DELLA BIODIVERSITÀ NEL MEDITERRANEO

SINTESI

Nei paesi mediterranei, vista la perdita degli ambienti umidi e le crescenti richieste di spazio degli ultimi decenni da parte dei settori turistico ed urbanistico, appare chiaro che la biodiversità nel Mediterraneo, soprattutto nelle zone umide e costiere, non può venir tutelata con la sola gestione delle risorse naturali. L'autore sottolinea come le aree protette si siano rivelate uno fra gli strumenti più efficaci per la conservazione della biodiversità in situ.

Parole chiave: aree protette, biodiversità, tutela dell'ambiente, Mediterraneo

UVOD

V naši zavesti se vse bolj krepi spoznanje, da je varstvo narave in okolja ne le neodtujljiva pravica in odgovornost narodov in njihovih držav, temveč skupna odgovornost - v našem odnosu do sosednjih držav - pa tudi skrb celotnega človeštva.

Zavarovana območja so po splošnem mnenju eno najučinkovitejših sredstev za ohranjanje biodiverzitete *in situ*, kar je tudi poudarjeno v 8. členu Konvencije o biotski raznovrstnosti. Seveda pa zavarovana območja niso edini način za ohranjanje narave in pokrajine. Prej bi rekli, da so vrhunec naravovarstvenih prizadevanj, nekakšen model za ohranjanje pokrajine v širšem smislu. Zavarovana območja so še posebno pomembna, ker na najboljši način - v večini primerov tudi edini - ohranjajo biodiverziteto. Naravni rezervati in narodni parki so najprimernejši za zavarovanje redkih in ogroženih vrst, saj zagotavljajo, da se ohranjajo značilni vzorci različnih tipov habitatov. Poleg tega so zavarovane pokrajine (krajinski in regijski parki) učinkovito sredstvo za ohranjanje načina življenja, ki je v sozvočju z naravo in vzorčni primer za iskanje oblik sonaravnega razvoja podeželja. Zavarovana območja tudi bogatijo kakovost človekovega življenja, predvsem kot prostor za rekreacijo. Dajejo nam priložnost za navdih, pa tudi prostor za sproščanje, uživanje in učenje. Predvsem pa so vir človekove umske, telesne in duhovne obnove.

Pa vendar zavarovana območja pokrivajo Evropo zelo neenakomerno in tudi sistem zavarovanih območij je po mednarodnih merilih precej neučinkovit.

V tem smislu je treba razumeti prizadevanja Svetovne zveze za ohranitev narave IUCN (The World Conservation Union), Svetovnega sklada za naravo (WWF - The World Wide Fund for Nature), Evropske zveze naravnih in narodnih parkov (EUROPARC Federation), Svetovnega centra za ohranitev narave (World Conservation Monitoring Center) in BirdLife International, da uresničijo prvi akcijski načrt, imenovan *"Parki za življenje"*, za zavarovana območja v Evropi. Načrt je rezultat sodelovanja med državami, vladnimi službami in agencijami, nevladnimi organizacijami in posamezniki v Evropi in je nekakšen evropski konsenz o tem, kakšno delo je še treba opraviti na tem področju.

Kakšen je namen akcijskega načrta?

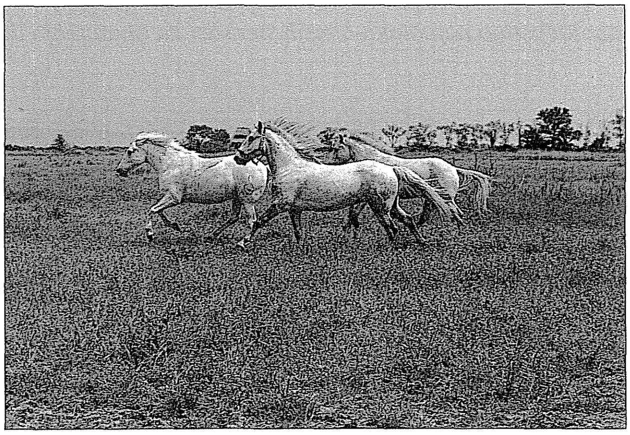
Odgovor na to vprašanje je leta 1994 zapisala Komisija za narodne parke in zavarovana območja (WCPA) in se glasi takole: *"Da zagotovi ustrezno in učinkovito omrežje primerno upravljanih zavarovanih območij v Evropi."*

Kakšne dejavnosti obsega akcijski načrt?

"Parki za življenje" je dokument, ki je nastal z namenom pomagati vladam in upravljalcem zavarovanih območij, da zagotovijo ustrezno in učinkovito omrežje dobro upravljanih zavarovanih območij v Evropi.

Načrt obsega tri vrste dejavnosti. Prvič, vsebuje mnoge že obstoječe pobude, ki govorijo, da je bilo v Evropi na področju zavarovanih območij že veliko narejenega. Drugič, daje nasvete, predvsem vladam, glede zavarovanih območij, še posebej vključevanje zavarovanih območij v postopkih načrtovanja kmetijskih, gozdarskih, turističnih in drugih planskih odločitev. Tretjič, predvideva, da bodo uresničeni tako imenovani prednostni projekti, ki bodo obravnavali specifično problematiko načrtovanja in upravljanja z zavarovanimi območji.

Svetovna mreža zavarovanih območij obsega več kot 30.000 območij (ta analiza zajema vsa zavarovana območja, ne glede na njihovo velikost). Skupna zavarovana površina presega 13 milijonov km², kar pomeni nekaj več kot 9% kopnega. Evropska mreža obsega 9.335 zavarovanih območij na več kot 600.000 km² ali na 12% njene celotne kopenske površine (WCMC, 1994).



Sl. 1: Konji na paši v francoskem mokrišču Camargue. (Foto: I. Škornik)
Fig. 1: Horses at the pasture in the French wetland Camargue. (Photo: I. Škornik)

MEDNARODNI DOGOVORI IN DRUGE POBUDE ZA ZAVAROVANA OBMOČJA V SREDOZEMSKI REGIJI

Poleg že omenjene Konvencije o biotski raznovrstnosti so za razglašanje zavarovanih območij v srednjeevropskem in sredozemskem prostoru pomembni še naslednji mednarodni dogovori (podrobneje so predstavljeni v Skoberne, 1997):

Ramsarska konvencija (1971)

Konvencija o mokriščih, ki imajo mednarodni pomen, zlasti kot prebivališča močvirskih ptic *(Ram-*

sarska konvencija), je bil prvi svetovni sporazum o varovanju in razumni rabi naravnih virov. *Ramsarska konvencija* je okvir za mednarodno sodelovanje pri varovanju in razumni rabi mokrišč. Konvencija je podrobneje predstavljena v publikaciji Ramsarska konvencija in slovenska mokrišča (Sovinc, 1999).

Pobuda MedWet

MedWet je dolgoročna regionalna pobuda pod pokroviteljstvom Ramsarske konvencije in drugih vladnih in nevladnih organizacij, katerih namen je zavarovati sredozemska mokrišča in spodbujati k njihovi razumni rabi. Med *"Konferenco o sredozemskih mokriščih"* v Benetkah leta 1996 je bila potrjena tako imenovana *"Strategija za sredozemska mokrišča",* ki temelji na *"Strateškem načrtu 1997-2002 Ramsarske konvencije".* Njen glavni namen je zaustaviti degradacijo ali uničevanje sredozemskih mokrišč in tako prispevati k ohranjanju biodiverzitete in sonaravnega razvoja v tem območju. V njej je navedena vrsta splošnih ciljev, ki naj bi jih dosegli z različnimi akcijami na mednarodni, regionalni in lokalni ravni.

Konvencija o svetovni dediščini (1972)

Osnovno poslanstvo te konvencije o varovanju svetovne kulturne in naravne dediščine je natančno definirati in ohraniti to dediščino. Naravna dediščina je definirana kot:

"skupek naravnih značilnosti, sestoječih iz fizičnih in bioloških formacij ali skupin takšnih formacij, ki so izjemne svetovne vrednosti z estetskega ali znanstvenega vidika",

kot *"geološke in fiziografske formacije in natančno določena območja, ki zajemajo habitate ogroženih živalskih in rastlinskih vrst izjemne svetovne vrednosti z vidika znanosti ali ohranjanja narave",*

in/ali kot *"naravne lokalitete ali natančno določena naravna območja izjemne svetovne vrednosti z vidika znanosti, ohranjanja narave ali naravne lepote".*

UNESCO biosferni program (1976)

Ta interdisciplinarni program raziskovanja in usposabljanja v okviru naravoslovnih in družboslovnih ved je namenjen spodbujanju razumne rabe in varovanju virov v biosferi ter izboljševanju odnosov med ljudmi in okoljem po vsem svetu. Sloni na oblikovanju in upravljanju biogeografsko reprezentativne mreže biosfernih rezervatov, kjer se ohranjanje ekosistemov in njihove biodiverzitete povezuje s sonaravno uporabo naravnih virov, ustreznimi raziskavami, spremljanjem stanja (monitoringom) in izobraževanjem v dobro krajevnih skupnosti.

Smernica EU za varstvo ptičev (1979)

S temi smernicami Evropske zveze so bile članicam Evropske unije naložene stroge pravne obveznosti, med njimi tudi ta, da je treba znotraj posebno varovanih območij ohranjati populacije prostoživečih ptic.

Smernice EU FFH ("flora, favna, habitati"; 1992)

Namen teh smernic Evropske zveze je zagotoviti ohranitev biodiverzitete z varovanjem naravnih habitatov prostoživečih živali. V smernicah je predvideno, da se najkasneje do leta 2000 osnuje omrežje varovanih območij v Evropski zvezi. S tem omrežjem, ki ji pravimo tudi Natura 2000, naj bi ohranjali razširjenost in številnost ogroženih vrst in habitatov, tako kopenskih kot morskih. Natura 2000 zajema tudi območja za posebno varovanje, tako kot to določajo Smernice za varstvo ptičev. Takšna območja so lokalitete, ki so pomembne za vso evropsko skupnost in jih članice Evropske zveze zavarujejo s pravnimi, administrativnimi in/ali pogodbenimi akti, ki določajo, da je treba za ohranjanje naravnih habitatov in populacij vrst, ki so jim lokalitete namenjene, upoštevati potrebne varstvene ukrepe.

Barcelonska konvencija (1976)

Prvotni namen *Barcelonske konvencije* je bil zmanjšati onesnaževanje v Sredozemskem morju. Leta 1982 je bil sprejet tretji predpis glede posebno zavarovanih območij v Sredozemskem morju, ki pa naj bi ga v kratkem nadomestili z novim (potrjen je bil že leta 1995), imenovanim "predpis za posebno zavarovana območja in biodiverziteto". Namen posebej zavarovanih območij je ohraniti:

a) značilne tipe ustrezno velikih obalnih in morskih ekosistemov, da bi se zagotovila njihova dolgoročna sposobnost za življenje in ohranila njihova biodiverziteta;
b) habitate, ki jim grozi, da bodo v svojih naravnih sredozemskih območjih razširjenosti izginili, ali katerih območje se je zmanjšalo zaradi njihove regresije ali pa zaradi bistveno omejene površine;
c) habitate s kritično stopnjo preživetja za močno ogrožene ali endemične živalske in rastlinske vrste;
d) lokalitete posebnega pomena zaradi njihovih znanstvenih, estetskih, kulturnih ali izobraževalnih vrednosti.

BIODIVERZITETA V SREDOZEMLJU

V *"Parkih za življenje"* je sredozemsko območje obravnavano kot eno tistih, ki jih je treba obravnavati prednostno. Čeprav v sredozemskem bazenu ni ostalo skoraj nič od njegovega prvotnega naravnega okolja, ostaja zaradi svoje bogate krajinske in kulturne dediščine, izredno zanimive zgodovine in toplega podnebja eno najbolj priljubljenih evropskih letovišč. Zaradi takšnega razvoja in še cele vrste drugih okoliščin so ogroženi mnogi naravni viri, ki so se še ohranili v tem območju. Močno ogrožena so predvsem mokrišča: v zadnjih nekaj desetletjih je bilo v Grčiji, Franciji, Italiji in Španiji uničenih med 60 in 70% mokrišč.

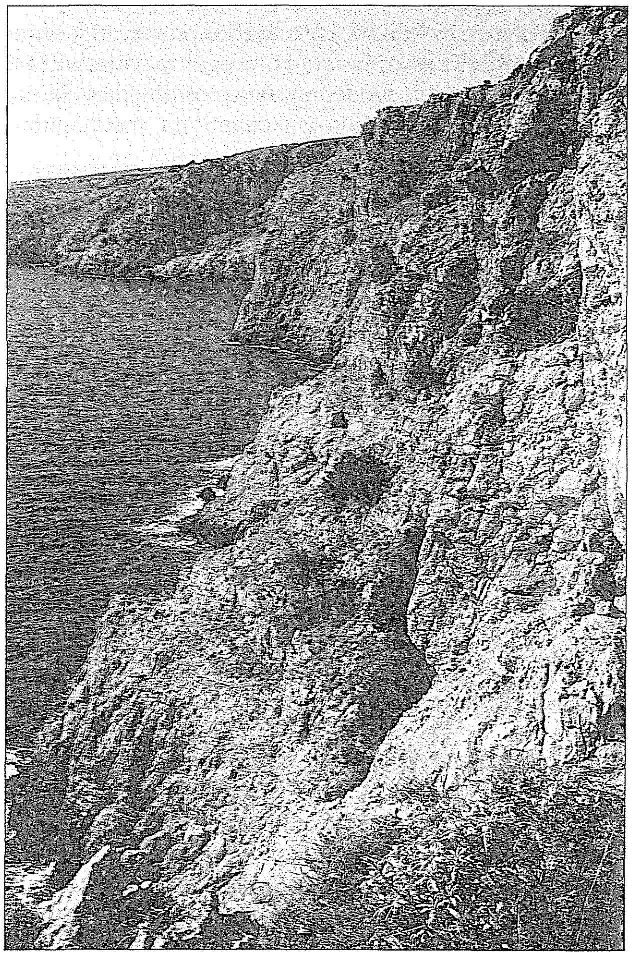
Sredozemsko območje je znano po pestri biodiverziteti in endemičnih vrstah, posebno rastlinah, ki jih više na severu ni. Bogata je tudi ptičja favna, posebno zaradi številnih preletnih vrst. Sredozemsko morje je poleg tega dom morskih želv in nekaterih redkih sesalcev, kakršna je medvedjica *(Monachus monachus)*. To pomeni veliko odgovornost za vlade sredozemskih držav, saj k njihovim ozemljem sodi precejšen delež evropske biodiverzitete in še posebno ogroženih vrst. Kakih 80% rastlinskih vrst, na primer, katerih rastišča in habitate je treba zaščititi v skladu s smernicami Evropske zveze o habitatih, je prav iz sredozemskih držav.

Tab. 1: Diverziteta višjih rastlin v sredozemskih in drugih evropskih državah (vir: WCMC, 1994).
Tab. 1: Vascular plants diversity in the Mediterranean and other European countries (source: WCMC, 1994).

Država	Število prostoživečih vrst	Število endemičnih vrst (vrst, ki jih drugod ni)	Število rastlinskih vrst po 2. aneksu smernic EU o habitatih
Grčija	4992	742	36
Italija	5598	712	45
Španija	4916	941	87
Poljska	2300	3	ni članica EU
Danska	1252	1	3
Irska	950	0	0

Glede na izgubo mokrišč v sredozemskih državah v zadnjih nekaj desetletjih in zaradi vse večjih zahtev turizma in drugih posegov v prostor v teh državah postaja jasno, da biodiverzitete v Sredozemlju, posebno na mokriščih in obalnih območjih, ne bo mogoče ohraniti zgolj s sonaravno uporabo virov. Če želimo, da se krhka in enkratna naravna dediščina v Sredozemlju ohrani, je treba temeljito spremeniti odnos do turizma in njegovega potencialno zelo škodljivega vpliva na biodiverziteto in hkrati do tradicij in kultur v zavarovanih območjih. V nekaterih zavarovanih območjih turizma preprosto ne bi smelo biti!

V *"Parkih za življenje"* je zapisano, da je poglavitni cilj sredozemske strategije o mokriščih *"pravno zaščititi najpomembnejša mokrišča v tem območju"*. K temu dodajmo, da bi bilo treba čim več ogroženih sredozemskih naravnih ali naravi podobnih območij opredeliti kot zavarovana območja IUCN 1. in 2. kategorije (tako imenovani strogo določeni naravni rezervati in narodni parki) (IUCN, 1994). Preostala, še ohranjena večja sredozemska mokrišča, bi morala dobiti status narodnih parkov. Po drugi strani pa v Sredozemlju, kjer je voda redka dobrina, obstajajo prezrta mnoga manjša mokrišča, ko ocenjujemo biodiverzitetno vrednost teh površin. Tu bi morali razglasiti *t.i.* mikro-rezervate in strogo določene naravne rezervate (n.pr. osamljeni otočki s kolonijami gnezdečih ptic ali votline v obalnem morju, kjer domuje medvedjica, ali pa npr. značilni vaški kali in presihajoče mlake v slovenskem submediteranskem in kraškem pasu). Treba je jasno povedati, da v strogo določenih naravnih rezervatih ni mogoča nobena vrsta turizma in da je turizem močno vprašljiv tudi v narodnih parkih. Tudi druge spremembe namembnosti teh površin so nedopustne.



Sl. 2: Strme prepadne stene nad morjem na otoku Cresu nudijo gnezdilno nišo koloniji beloglavih jastrebov** Gyps fulvus. **(Foto: I. Škornik)
Fig. 2: Steep walls above the sea surface offer an excelent breeding site for the colony of Griffon Vulture** Gyps fulvus **on the island of Cres. (Photo: I. Škornik)

Naslednji primer nesprejemljive dejavnosti v narodnih parkih in strogo določenih naravnih rezervatih je lov, ki ga pogosto promovirajo kot del turističnih dejavnosti. Močni lovski lobiji v Franciji, Italiji, Grčiji in Španiji pogosto nasprotujejo ustanavljanju novih parkov, hkrati pa lovci nadaljujejo s svojim početjem znotraj nekaterih obstoječih regionalnih parkov.

Morsko okolje je vsaj delno obravnavano v ramsarski definiciji mokrišč. Morskih zavarovanih območij je premalo in v večini sredozemskih držav z njimi sploh ne upravljajo. Predpis Barcelonske konvencije o posebno zavarovanih območjih določa nekakšen glavni mednarodni okvir za ustanavljanje morskih zavarovanih območij v Sredozemlju. Uresničevanje tega predpisa podpira *Regionalni center za posebno zavarovana območja (RAC/SPA),* ki je del tako imenovanega Sredozemskega akcijskega načrta in ima sedež v Tunisu. Podpora prihaja tudi iz *Mreže sredozemskih zavarovanih območij (MEDPAN),* ki je pod zaščito Svetovne banke in dobiva podporo od *Programa za sredozemsko okoljsko tehnično pomoč (METAP).*

ZAKLJUČKI IN PRIPOROČILA

- Zavarovana območja so po splošnem mnenju eno najučinkovitejših sredstev za ohranjanje biodiverzitete *in situ;*
- Sredozemlje je tako imenovana "vroča točka" biodiverzitete, ki pa je ne moremo ohraniti brez nadaljnje zaščite v sklopu zavarovanih območij;
- Cilji, kot so navedeni v Strategiji za pravno zaščito vseh sredozemskih mokrišč (MedWet and Convention on Wetlands, 1998), so opisani tudi v *"Parkih za življenje",* prvem akcijskem načrtu za zavarovana območja v Evropi;
- Čeprav je bil turizem označen kot poglavitna grožnja biodiverzitetnim vrednotam v Sredozemlju, je treba vendarle reči, da sta turizem in naravovarstvo pogosto lahko združljiva in medsebojno koristna, toda le v primeru, če ti dejavnosti opravljamo sonaravno in v za to primernih območjih;
- Kar največ preostalih sredozemskih naravnih ali naravni podobnih območij je treba zavarovati po merilih IUCN (1. in 2. kategorija upravljanja zavarovanih območij: strogo določeni naravni rezervati in narodni parki), kjer je turizem bodisi strogo omejen in nadzorovan ali pa sploh ni dovoljen;
- Mikrorezervati se zdijo še posebej pomembni za ohranjanje manjših sredozemskih mokrišč in drugih habitatov;
- Morskih zavarovanih območij je premalo, in ker v večini sredozemskih držav zanje niso pripravljeni načrti upravljanja, je treba na tem področju nujno ukrepati;
- Vsako zavarovano območje bi moralo imeti svoj enotni upravljalski načrt. Za vsako zavarovano območje bi bilo treba razviti akcijski načrt za sonaravni turizem, in sicer kot del enotnega upravljalskega načrta.

PROTECTED AREAS AS AN INSTRUMENT FOR THE CONSERVATION OF BIODIVERSITY IN THE MEDITERRANEAN

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SUMMARY

In view of the loss of many wetlands in the Mediterranean countries during the last few decades and due to the increasing demands by tourism and other pressures exerted on nature through physical planning it is becoming clear that conservation of biodiversity in the Mediterranean, particularly in wetlands and coastal areas, will not be possible merely with sustainable use of resources. The author calls our attention to the fact that protected areas are one of the most effective means for the conservation of biodiversity in situ.

Key words: protected areas, biodiversity, nature conservation, the Mediterranean

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POKRAJINSKA OGROŽENOST IN UKREPI ZA ZAŠČITO KRAŠKEGA IZVIRA BISTRICA

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IZVLEČEK

Avtor je v prispevku ugotavljal, kakšna je pokrajinska ogroženost kraškega izvira Bistrica, ter podal predlog zaščitnih ukrepov za njegovo zavarovanje. Vodovarstveni ukrepi obsegajo sanacijo spodnjega kamnoloma in športnega strelišča na Črnih njivah, komunalno ureditev turističnega naselja Sviščaki ter ureditev cestnega omrežja v njegovem zaledju. Obenem je treba za zagotavljanje zdravstvene ustreznosti izvira organizirati učinkovit nadzor nad uresničevanjem preventivnih zaščitnih ukrepov v gradbeni, gozdarski in kmetijski dejavnosti.

Ključne besede: pokrajinska ogroženost, kraški izvir Bistrica, vodovarstveni ukrepi, vodovarstvena območja

VULNERABILITÀ AMBIENTALE DELLA SORGENTE CARSICA BISTRICA E POSSIBILI MISURE DI PROTEZIONE

SINTESI

L'autore esamina la vulnerabilità ambientale della sorgente carsica Bistrica e propone una serie di misure di protezione e mantenimento. Tali misure includono il risanamento della cava inferiore e del poligono di tiro sportivo Črne njive, nonché adeguate misure igienico-sanitarie al villaggio turistico di Sviščaki e la regolazione del sistema stradale verso l'entroterra. L'autore sottolinea la neccessità di uno stretto controllo delle attività edilizie, forestali e agricolturali, al fine di assicurare un'appropriata qualità dell'acqua potabile proveniente dalla sorgente.

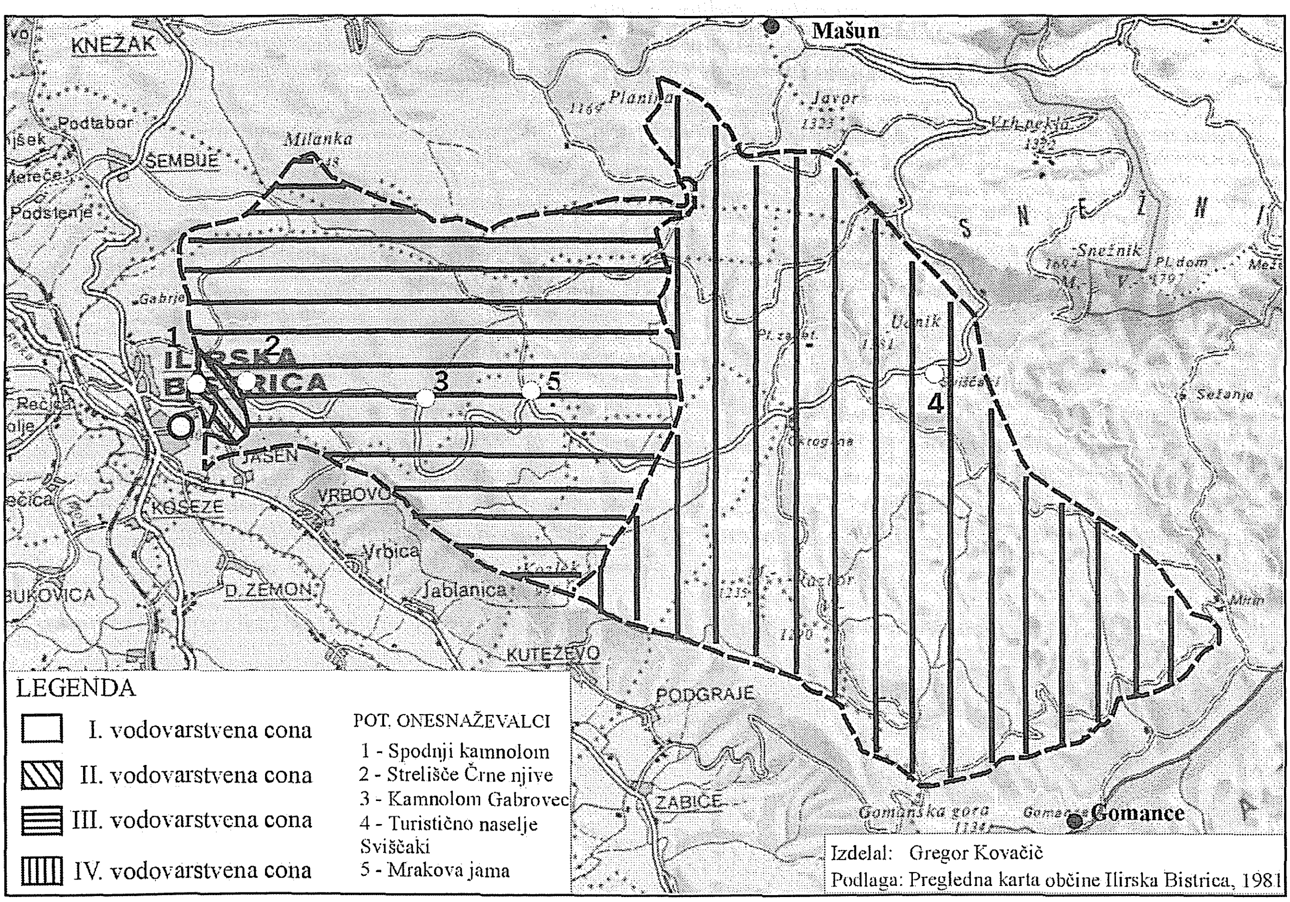
Parole chiave: vulnerabilità ambientale, sorgente carsica Bistrica, misure di protezione della sorgente idrica

UVOD

Za oskrbo s pitno vodo v Sloveniji so zelo pomembni obsežni kraški vodonosniki, ki so pomembna zaloga pitne vode. Vendar so kraška območja z vidika varovanja vode zelo problematična, saj se negativni vplivi zaradi slabe filtracije in relativno hitrega in zapletenega podzemeljskega toka lahko dolgo kažejo na kakovosti pitne vode. Razmere na teh območjih je moč obvladovati le z dolgoročnimi, pretežno preventivnimi ukrepi, ki so usmerjeni v selekcioniranje človekovih dejavnosti, sprejemljivih v tem prostoru, in z doslednim uresničevanjem preventivnih zaščitnih ukrepov. V Sloveniji kraški izviri pokrivajo približno 43% potreb po pitni vodi (Plut, 2000), pomembni pa so tudi za oskrbo občine Ilirska Bistrica. Eden pomembnejših kraških izvirov v Sloveniji, zlasti pa na območju jugozahodne Slovenije, je kraški izvir Bistrica (Brumen *et al.,* 1991), ki s pitno vodo oskrbuje pretežni del občine Ilirska Bistrica, nekaj naselij v občini Hrpelje-Kozina ter del Kvarnerja.

Vsi viri pitne vode v občini Ilirska Bistrica (30 virov pitne vode v občini) so zavarovani z Odlokom o določitvi varstvenih pasov in ukrepov za zavarovanje vodnih virov (PN Uradne objave, 39/1985), vendar pa vodovarstveni pasovi niso izdelani na podlagi predhodnih hidrogeoloških raziskav hidrogeografskih zaledij posameznih virov pitne vode. Tako so vodovarstvena območja določena le na osnovi razdalj od zajetij, režim varovanja pa je v primerjavi z obstoječimi, novejšimi metodologijami o zavarovanju podzemne pitne vode preblago in slabo definiran.

Na podlagi hidrogeoloških raziskav zaledja kraškega izvira Bistrica, ki jih je Geološki zavod Ljubljana opravil v letu 1989 (Juren & Krivic, 1989), so bile izdelane strokovne podlage za njegovo zavarovanje. Osnove za določitev vodovarstvenih pasov in območij so bile v omenjeni študiji litološka zgradba terena, površinske in podzemske razvodnice, tektonika in hidrogeološke karakteristike ozemlja. Hidrogeografsko zaledje kraškega izvira Bistrica je tako razdeljeno na štiri vodovarstvene pasove, ki skupaj obsegajo prek 95 km^2 ozemlja (Sl. 1), določen pa je tudi vodovarstveni režim, ki bi se v posameznih pasovih zaščite moral uresničevati. Varstveni pasovi so bili izdelani na podlagi obstoječih podatkov, kar zaradi specifičnosti kraškega terena ne zadostuje. Upoštevali so hidrogeografski (površinske ra-



Sl. 1: Vodovarstveni pasovi kraškega izvira Bistrica in njegovi potencialni onesnaževalci. (Juren & Krivic, 1989)
Fig. 1: The water-protection areas of the Bistrica karst spring and its potential pollutants. (Juren & Krivic, 1989)

zvodnice), hidrogeološki (podzemske razvodnice), litološki (kolektorji-prepustne plasti: apnenci, dolomiti; izolatorji-nepropustne snovi: fliš) in hidrodinamični kriterij (hitrost pretoka vode od potencialnega mesta onesnaževanja do izvira in čas zadrževanja vode v podzemlju z ozirom na samočistilne sposobnosti in eventualno možnost posredovanja v primeru nesreče z izlitjem škodljivih snovi). Točnost podzemnih poti bi morali potrditi s sledilnimi poskusi ali pa z merjenjem piezometrične gladine kraške talne vode v globokem krasu Snežniške planote. Obe metodi nam omogočata določitev podzemnih vodnih povezav, smeri in hitrost odtoka padavinske vode v notranjosti dobro razvitega kraškega vodonosnega sistema (Ford & Williams, 1992). Na osnovi hidrogeoloških raziskav (Juren & Krivic, 1989) je bil na pobudo Komunalno stanovanjskega podjetja Ilirska Bistrica, ki je upravljalec omenjenega izvira, izdelan predlog o zaščiti kraškega izvira Bistrica (KSP Ilirska Bistrica, 1995), ki pa do danes še ni bil sprejet z občinskim odlokom. Zaščitni ukrepi se ne uresničujejo, kar pomeni, da je regionalno pomembni vir pitne vode praktično nezavarovan.

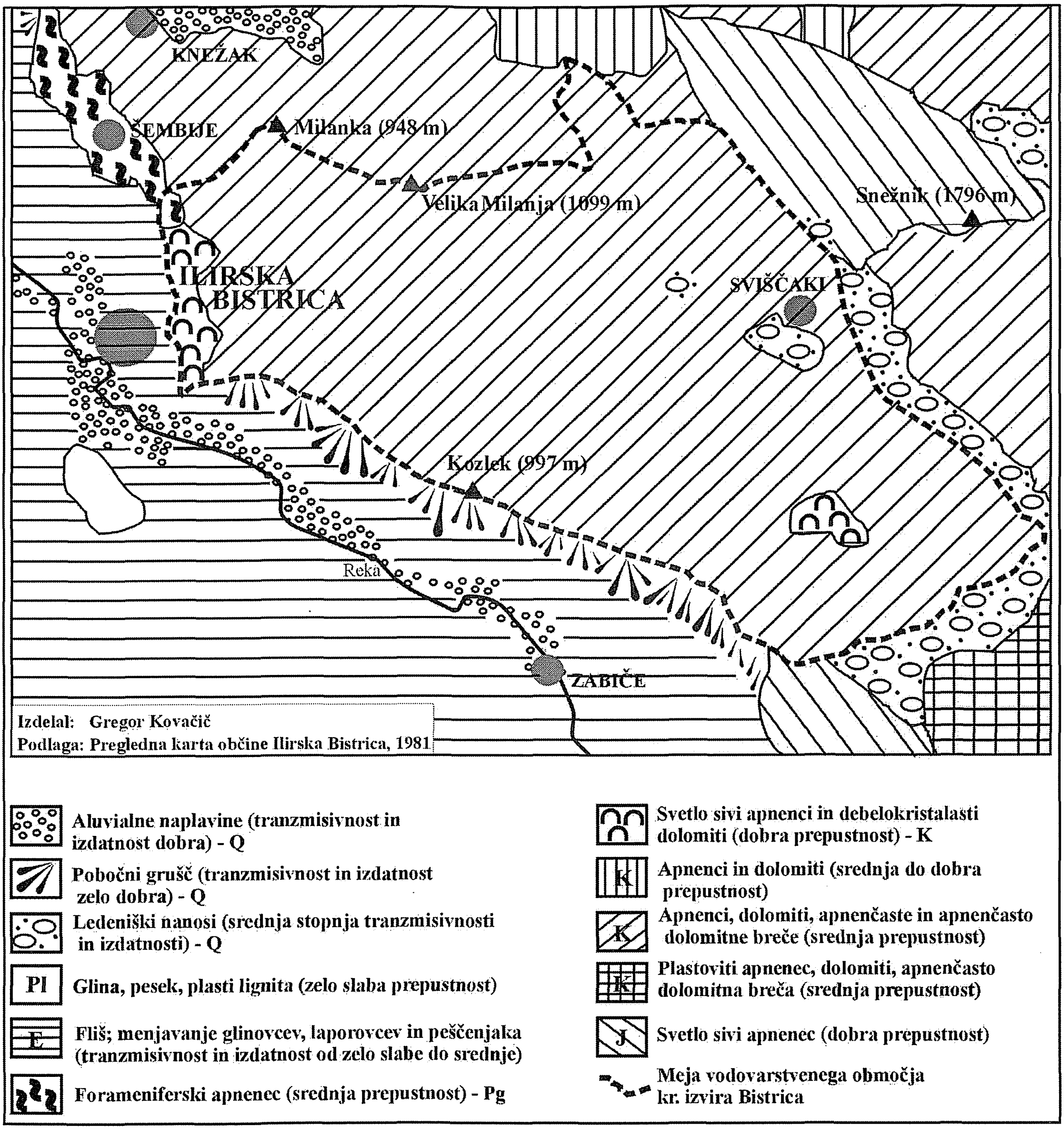
HIDROGEOLOŠKE ZNAČILNOSTI OBMOČJA

Hidrogeografsko zaledje kraškega izvira Bistrica leži v celoti na območju Snežniške planote, ki se v strmi stopnji dviga iznad doline Reke. Obseg celotnega vodovarstvenega območja in posameznih con zaščite izvira Bistrica prikazuje slika 1. Na severu poteka hidrogeografska meja po stari razvodnici med Pivko in Reko, ki se je izoblikovala že v pliocenu. Ta poteka od naselja Knežak proti vzhodu po vrhovih Milanka (948 m.n.v.), Velika Milanja (1099 m.n.v.) do Javorja (1065 m.n.v.) (Melik, 1951). Danes markantno sleme ponazarja mejo med zunanjimi vodovarstvenimi pasovi izvira Bistrica ter vrtin K-1 in K-3 pri Knežaku. Na omenjenem območju prihaja do bifurkacije, saj nizke vode v glavnem odtekajo v izvir Bistrica, visoke vode pa odtekajo proti Pivki (Habič, 1984). Na severozahodu širše vodovarstveno območje izvira Bistrica meji na širši varstveni pas kraškega izvira Podstenjšek. Na jugu poteka meja vodovarstvenega območja po narivnem robu, pod katerim izvirajo številni manjši izviri, zajeti za vodno oskrbo prebivalcev Podgore. Vodooskrbna območja izvirov v Podgori se prepletajo med seboj ter s hidrogeografskim zaledjem kraškega izvira Bistrica. Nejasna je meja IV. vodovarstvene cone zaščite kraškega izvira Bistrica, ki so jo zaradi slabšega poznavanja terena in da bi se izognili morebitnim nepremišljenim posegom v naravo, pomaknili do roba dinarskega preloma, kjer so opazne vidne geološke spremembe terena (Juren & Krivic, 1989).

Snežniška planota pripada hidrološkemu tipu globokega raztočnega krasa in je najpomembnejše vodooskrbno ter hkrati vodovarstveno območje v občini Ilirska Bistrica, saj zbira padavinsko vodo za zajetja Bistrica, Podstenjšek, vrtini K-1 in K-3 (Knežak) ter več manjših lokalnih zajetij v Podgori in izvirkov nad Knežakom. Za ta tip krasa je pomembna avtohtona padavinska voda, ki prenika v kraško podzemlje in odteka v različne smeri proti kraškim izvirom na obrobju. Snežniška planota je razvodno območje, saj se njen jugovzhodni del odmaka v porečje Riječine (Hrvaška), severovzhodni del pripada črnomorskemu povodju, zahodni predeli pa napajajo kraške izvire, ki prihajajo na dan ob stiku s flišem in so sestavni del porečja Reke (Sl. 2). Snežniško planoto gradijo pretežno apnenci, dolomiti, apnenčaste in dolomitne breče jurske in kredne starosti, tu in tam pa se v majhnem obsegu pojavljajo tudi ledeniške morene in aluvialne naplavine (Šikić *et al.*, 1972; Šikić & Pleničar, 1975). Kredne plasti snežniškega masiva so na zahodu narinjene prek flišnih plasti brkinske sinklinale, kar dokazujeta flišnati tektonski okni pri Zagorju in Knežaku, ki sta se pokazali potem, ko je vodna erozija odstranila del apnenca, ki je prekrival spodaj ležeči fliš (Pleničar, 1968). Nariv je jasno izražen v markantni stopnji nad zgornjim tokom Reke v Podgori.

Za določitev padavinskega zaledja in nivoja napajalnega območja so zanimivi kaverozno-razpoklinski ter dobro in srednje prepustni kredni in paleogenski apnenci, dolomiti ter breče, ki so tektonsko zelo pretrti, kar še povečuje njihovo propustnost. Tektonika je lahko razlog za razvoj podzemnih poti, lahko pa deluje kot bariera podzemni vodi, če so tektonske cone milonitizirane (na območju dolomita). Omenjene kamnine se razprostirajo severovzhodno od izvira Bistrica, ki je na najnižji točki kontakta nepropustnih plasti fliša in apnenca. Padavinsko in vodooskrbno območje, polno vrtač, dolin in brezen, sega do dinarskega preloma, ki meji na apnence in debelokristalaste dolomite jurske starosti. Manjše predele prekrivajo tudi usedline z medzrnsko poroznostjo in srednjo stopnjo izdatnosti in tranzmisivnosti, ki se pojavljajo v okolici počitniškega naselja Sviščaki, v Črni dragi in v Črnem dolu. Gre za pesek in slabo zaobljen prod ledeniških moren črnodolskega ledenika, ki se je v ledeni dobi raztezal od vrha Snežnika proti zahodu (Šifrer, 1959). Od preloma dalje vode gravitirajo že proti Kvarnerju, zaledju reke Pivke in Cerkniškemu jezeru, ki sodita k porečju Ljubljanice (Juren & Krivic, 1989; Pavlovec & Pleničar, 1980; Šikić *et al.*, 1972; Šikić & Pleničar, 1975).

Vodooskrbno območje označuje razvit globoki kras Snežniške planote z dobro prepustnostjo, kar pomeni, da se kraška talna voda v notranjosti pretaka zelo hitro, čeprav so hitrosti v prežeti coni zelo majhne in znašajo le nekaj cm/s. Posledica pretakanja po kanalih je, da skorajda ne prihaja do mehaničnega čiščenja, saj so pretoki kraške podzemne vode v primerjavi z nekraškimi podzemskimi zelo hitri in skrajšajo čas že tako



Sl. 2: Geološke in hidrogeološke značilnosti območja (povzel in priredil po Šikić et al.*, 1972; Šikić & Pleničar, 1975; Pavlovec & Pleničar, 1980; Juren & Krivic, 1989).*
Fig. 2: Geological and hidrogeological characteristics of the region (based on Šikić et al.*, 1972; Šikič & Pleničar, 1975; Pavlovec & Pleničar, 1980; Juren & Krivic, 1989).*

omejenega biokemijskega čiščenja, kar slabša njeno kakovost. Hidrogeografsko zaledje kraških virov pitne vode je tako zaradi velike prepustnosti tal in omejenega naravnega čiščenja zelo izpostavljeno onesnaženju in močno pokrajinsko občutljivo (Ford & Williams, 1992; Plut, 1998; Šušteršič, 1992).

METEOROLOŠKE ZNAČILNOSTI OBMOČJA

Podatki o padavinah za meteorološko postajo Ilirska Bistrica (414 m.n.v.) kažejo, da letno v dolinskem območju pade 1448 mm padavin. Proti vzhodu padavine zaradi orografske pregrade naraščajo ter na zahodnem robu Snežniške planote presežejo 1800 mm. Podatki za Mašun (1022 m.n.v.; 2041 mm/letno) in bolj južno ležeče Gomance (924 m.n.v.; 2738 mm/letno) kažejo, da se količina padavin proti vršnim predelom Snežniške planote še veča in doseže približno 2500 mm, na najvišjih predelih pa celo 3000 mm. Snežniška planota je dobro namočena, kar je z vidika oskrbe s pitno vodo zelo ugodno (Zupančič, 1995, 1998).

Povprečna letna / januarska / julijska temperatura zraka na meteorološki postaji Ilirska Bistrica znaša 9,6°C / 0,8°C / 18,7°C. Temperature se od roba Snežniške planote proti notranjosti nižajo, kar se da sklepati iz podatkov meteoroloških postaj Gomance in Mašun. Povprečna letna / januarska / julijska temperatura zraka na Gomancah znaša 6,7°C / -1,5°C / 15,6°C, na Mašunu pa 5,6°C / -3,1°C / 14,6°C. Proti vršnim delom planote se temperature še znižajo, kjer znašajo okrog 2°C / -6°C / 10°C (Klemenčič, 1959; Mekinda-Majaron, 1995).

Vodooskrbno območje kraškega izvira Bistrica v celoti leži na območju Snežniške planote, kjer je zaradi večje nadmorske višine in posledično nižjih temperatur izhlapevanje manjše, prepustna karbonatna litološka podlaga pa omogoča hitro prenikanje vode v globino, kar tudi zmanjšuje možnost izhlapevanja, povečuje pa vodni odtok.

MATERIALI IN METODE

S pomočjo podatkov o kakovosti kraškega izvira Bistrica, ki sem jih pridobil na ZZV Koper (Zavod za zdravstveno varstvo Koper), ter tehničnih podatkov o zajetju izvira, ki sem jih dobil na KSP Ilirska Bistrica, sem ugotavljal pokrajinske značilnosti omenjenega vodnega vira. S terenskim pregledom hidrogeografskega zaledja v letih 1999 in 2000 sem evidentiral potencialne onesnaževalce v zaledju ter skušal ugotoviti stopnjo njihovega ogrožanja in obremenjevanja kraškega izvira Bistrica, pri čemer sem dognanja s terena primerjal z rezultati analiz kakovosti pitne vode na zajetju.

Zaradi upoštevanja dejstva, da se pri varovanju pitne vode srečujemo tako s časovno kot tudi stroškovno komponento, sem temu primerno predlagane sanacijske in preventivne ukrepe za zaščito kraškega izvira Bistrica tudi časovno uvrstil glede na nujnost izvedbe. Pri tem sem upošteval čas pretoka podzemne kraške vode oziroma hitrost širjenja onesnaževala do zajetja (definirano z vodovarstvenimi pasovi) in potencialno nevarnost posameznega vira onesnaženja za omenjeno zajetje. Pri določanju ukrepov za zaščito sem izhajal iz vodovarstvenih ukrepov v posameznih vodovarstvenih conah, ki jih določa Pravilnik za določevanje vodovarstvenih območij podzemnih vodnih virov (Petauer & Veselič, 1997b, v nadaljnjem besedilu Pravilnik).

POKRAJINSKE ZNAČILNOSTI KRAŠKEGA IZVIRA BISTRICA

Reka Bistrica izvira neposredno nad starim delom mesta Ilirska Bistrica in se komaj po kilometru površinskega toka že izliva v reko Reko ter je njen stalen desni pritok. Bistrica izvira v manjši zatrepni dolini, voda priteka na dan ob stiku apnenca in fliša v nadmorski višini 420 metrov. Glede na izvor je voda podzemna, zbira pa se v vodonosniku s kraško poroznostjo. Izvir je zajet za vodno oskrbo.

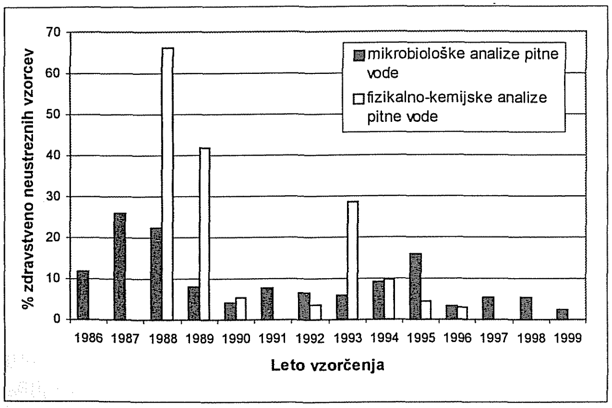
Kapaciteta izvira je 200,60 l/s, vendar je zaradi biološkega minimuma moč izkoristiti le 150,60 l/s. Voda priteka po približno 90 metrov dolgem tunelu do zidanega zajetja, od tod pa v čistilno napravo. Čistilna naprava je sestavljena iz dveh usedalnikov za posedanje grobih delcev umazanije, kjer se za pospešitev koagulacije po potrebi dodaja aluminijev sulfat. Sestavni del sta tudi dva peščena filtra z zmogljivostjo prečiščevanja kakih 74 l/s, kolikor je trenutni odvzem na zajetju. Voda priteka v čistilno napravo prosto, kar pomeni, da potem, ko nivo vode upade, voda ne priteka več v čistilni filter, temveč prek dezinfekcije (plinski klor) neposredno v omrežja posameznih vodovodnih sistemov občinskega vodovoda Ilirska Bistrica (KSP Ilirska Bistrica, 2000).

Nižinski vodovod (sistem "A") s pitno vodo oskrbuje območje Podgore, Brkinski vodovod (sistem "B") naselja v Brkinih, vodovod Visoki kras (sistem "C") območje Podgrajskega in Jelšanskega podolja ter Brda, sistem "D" pa mesto Ilirska Bistrica in naselja v njegovi bližini (Tab. 1). V obdobju, ko vode v lokalnih virih primanjkuje, oskrbuje vodovod Ilirska Bistrica s pitno vodo 12038 (84,6%) prebivalcev občine Ilirska Bistrica. Večji del leta oskrba iz lokalnih vodnih virov zadostuje in takrat se iz vodovoda Ilirska Bistrica oskrbuje 10548 (74,2%) prebivalcev občine. Vodovod Ilirska Bistrica ni pomemben samo z vidika oskrbe s pitno vodo v občini Ilirska Bistrica, saj se iz njega oskrbujejo tudi naselja zunaj meja občine. Do leta 1990 (pred priključitvijo na Kraški vodovod) se je z bistriško vodo oskrbovala večina naselij v podolju od Obrova do Kozine (območje občine Hrpelje-Kozina), po letu 1997 pa samo še naselja Obrov, Javorje, Tatre in Brezovo Brdo. Kraški izvir Bistrica je pomemben tudi za oskrbo sosednje Hrvaške. Po podatkih KSP Ilirska Bistrica se približno 40% načrpane vode iz zajetja Bistrica dovaja na ozemlje sosednje Hrvaške, kjer se z bistriško vodo oskrbujejo naselja v trikotniku od mejnega prehoda Rupa, Klane do naselja Matulji. Izgube na celotnem omrežju so velike in po ocenah znašajo od 35 do 45% (KSP Ilirska Bistrica, 2000; Občina Ilirska Bistrica, 2000).

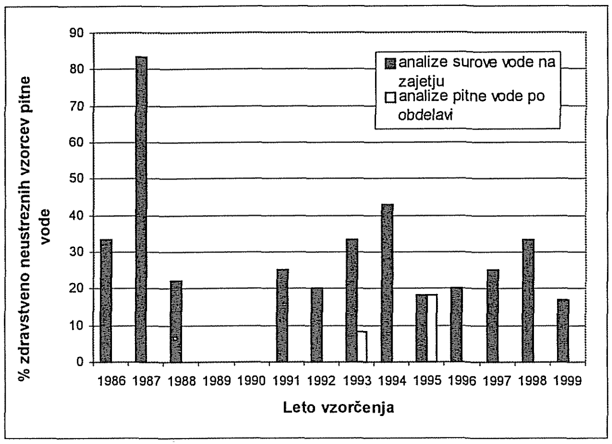
Tab. 1: Vodovodni sistemi vodovoda Ilirska Bistrica (KSP Ilirska Bistrica, 2000).
Tab. 1: Water-supply systems of the Ilirska Bistrica aqueduct (KSP Ilirska Bistrica, 2000).

Sistemi vodovoda Ilirska Bistrica	Naselja v občini Ilirska Bistrica, ki se stalno oskrbujejo iz sistema	Naselja v občini Ilirska Bistrica, ki se občasno oskrbujejo iz sistema
Nižinski vodovod – sistem "A"	Jasen	Vrbovo, Vrbica, Kuteževo, Podgraje, Zabiče
Brkinski vodovod – sistem "B"	Dobropolje, Zarečica, Zarečje, Harije, V. Bukovica, Soze, Tominje, Brce, Smrje, Prem, G. Bitnja, S. Bitnja, Kilovče, Ratečevo Brdo, Zajelšje, Pregarje, Huje, Gabrk, Rjavče, Prelože, Ostrožno Brdo, Janeževo Brdo, Čelje	
Vodovod Visoki kras – sistem "C"	Studena gora, Pavlica, Sabonje, V. Brdo, Starod, Račice, Podgrad, Podbeže, Hrušica, M. Loče, Jelšane, Nova vas	Dolenje, Novokračine
Vodovod Bistrica – sistem "D"	Ilirska Bistrica, Topolc, Rečica, D. Zemon, G. Zemon, M. Bukovica, zaselek Zemonska vaga	

Fizikalno-kemijska kakovost surove vode izvira je zelo visoka, saj zadnjih sedem let ne beležijo zdravstveno neustreznega vzorca. Nekoliko slabša je na vodovodnem omrežju, kar opozarja na zastarelo oziroma neustrezno napeljavo na posameznih odsekih vodovoda Ilirska Bistrica. Rezultati mikrobioloških analiz surove vode kažejo, da je bilo v zadnjih treh letih od 20 do 50% analiz zdravstveno neustreznih (Sl. 3). Vzrok zdravstvene neustreznosti surove vode so povečani *Escherichia coli*, presežen MPN skupnih koliformnih bakterij, preseženo število bakterij pri 22°C in pri 37°C. Po obdelavi v čistilni napravi (filtracija, dezinfekcija) postane voda mikrobiološko ustrezna (Sl. 4). Zaradi slabo grajenega omrežja na določenih odsekih vodovoda se enkrat do dvakrat letno na njem ugotovijo povečani *Escherichia coli*, presežen MPN skupnih koliformnih bakterij ter preseženo število bakterij pri 22°C (ZZV Koper, 2000).



Sl. 3: Rezultati mikrobioloških in fizikalno-kemijskih analiz pitne vode na vodovodu Ilirska Bistrica (ZZV Koper, 2000).
Fig. 3: The results of the microbiological and physical-chemical analyses of drinking-water samples taken from the Ilirska Bistrica water-supply system (ZZV Koper, 2000).



Sl. 4: Rezultati mikrobioloških analiz kraškega izvira Bistrica na zajetju in po obdelavi v čistilni napravi (ZZV Koper, 2000).
Fig. 4: The results of the microbiological analyses of drinking-water samples taken from the spring and after its treatment (ZZV Koper, 2000).

Pomen izvira z vidika oskrbe s pitno vodo je velik, saj ni moč najti primerno izdatnega vira pitne vode, ki bi v primeru kontaminacije izvira lahko nadomestil potrebe po pitni vodi na tem območju. Njegov pomen povečuje dejstvo, da s pitno vodo oskrbuje območja zunaj ozemlja občine Ilirska Bistrica in tudi države. Izvir je hkrati pomembna rezerva pri oskrbi s pitno vodo, saj je moč izkoristiti še enkrat toliko vode, kot se je trenutno dovaja v omrežje, zadovoljiva pa je tudi njegova mikrobiološka in fizikalno-kemijska kakovost.

POKRAJINSKA OGROŽENOST KRAŠKEGA IZVIRA BISTRICA

Z vidika varstva pitne vode je pozitivno to, da hidrogeografsko zaledje kraškega izvira Bistrica sestavljajo obsežni in neposeljeni gozdovi Snežniške planote, kljub temu pa je vodni vir ogrožen zaradi gozdarske, gradbeniške in turistične dejavnosti v njegovem ožjem in širšem zaledju.

Spodnji kamnolom in kamnolom Gabrovec

Samočistilne sposobnosti kraških vodonosnih sistemov so zelo skromne tudi zaradi tanke preperelinske odeje, ki pokriva ozemlje s karbonatno kamninsko podlago. Še tako skromna plast prsti pa pomeni dober filter za padavinsko vodo in tam, kjer je ta odstranjena, kot na primer v cestnih usekih in kamnolomih, lahko onesnaženje brez čiščenja hitro prodre v globino in potuje proti izvirom. Pri kamnolomih je treba biti posebno previden z vplivom na neposredni kraški odtok, kar pomeni, da je treba skrbno paziti na preprečevanje izlivov nafte in olj ter drugih strupenih ali škodljivih snovi, saj bi vsakršno njihovo izlitje lahko daljnosežno vplivalo na kvaliteto kraške talne vode (Šebela, 1997).

Na vodooskrbnem območju izvira Bistrica imamo dva večja kamnoloma, od katerih eden ne obratuje več (Sl. 1). Kamnolom apnenca Gabrovec leži približno štiri kilometre vzhodno od Ilirske Bistrice v III. vodovarstvenem pasu kraškega izvira Bistrica in ni urejen tako, da obratovanje ne bi ogrožalo kraške talne vode. Letna proizvodnja je približno 50-100.000 m^3 (Uprava RS za varstvo narave in Nizozemsko kraljevo združenje za varstvo narave, 1999). Delovni stroji za izkop kamenja stojijo prosto na delovišču, sanacijo onesnaženja tal z oljem ali nafto iz strojev pa zaradi hitrega prenikanja v notranjost ne bi bilo mogoče opraviti v celoti.

Drugi kamnolom leži mnogo bližje izvira Bistrica v II. vodovarstvenem območju, s svojimi površinami pa sega skoraj do I. vodovarstvenega pasu. Kamnolom apnenca je sicer opuščen, vendar ni saniran. Iz kamnoloma Gabrovec vanj vozijo kamenje, kjer ga predelujejo v pesek. Kamnolom je hkrati parkirišče za več delovnih strojev in težkih tovornjakov za prevoz kamenja. V kamnolomu je odloženih tudi nekaj starih in neuporabnih delovnih strojev, avtomobilov in tovornjakov, ki ogrožajo kakovost pitne vode v izviru Bistrica. V kamnolomu je tudi neurejeno in slabo zavarovano skladišče naftnih derivatov za potrebe delovnih strojev in tovornjakov. Nafta je skladiščena v sodih, podlaga ni vodotesna, morebitno izlitje nafte bi imelo velike posledice za zajetje Bistrica, saj bi bil udor nafte v podzemlje zaradi dobro propustne podlage zelo hiter. Slabo leto dni kamnolom uporabljajo kot odlagališče gradbenega materiala za širše območje Ilirske Bistrice. Odlaganje trdnih netopnih snovi z vidika varstva kraške talne vode ni problematično, vendar se nadzor nad sestavo odpadnega gradbenega materiala ne opravlja, tako da med odpadnim gradbenim materialom najdemo tudi številne nevarne odpadke, kot so ostanki embalaže različnih zaščitnih sredstev (barve, laki), avtomobilske gume, salonitne plošče in drugo. Zaradi karbonatne podlage, ki ni zaščitena s tankim slojem prsti, lahko te snovi hitro prodrejo v globino in izvir Bistrica za dalj časa onesnažijo.

Strelišče na Črnih njivah

Na delu nekdanjega vojaškega strelišča, ki leži v III. vodovarstvenem pasu izvira Bistrica, v neposredni bližini II. vodovarstvenega območja, se je po letu 1988 razvilo športno strelišče na glinaste golobe (Sl. 5). Aktivna površina strelišča je v plitki vrtači, ki jo obrašča strnjen borov gozd. Lega v plitki vrtači pogojuje nekoliko debelejšo plast prsti, ki je pomemben zaščitni filter za padavinsko vodo. Ta se na poti v notranjost obogati s svincem, ki ga vsebujejo šibrni naboji pušk za športno streljanje na leteče cilje - disciplino Trap. Uredba o vnosu nevarnih in rastlinskih gnojil v tla (UL RS 68/1996, v nadaljnjem besedilu Uredba) določa največji letni dovoljeni vnos svinca in njegovih spojin v tla, ki ne sme presegati 2,5 kg/ha. Posamezen naboj tehta 24 gramov, kar pomeni, da bi glede na velikost strelišča, ki pokriva nekaj več kot 2 ha, že 200 izstreljenih nabojev letno pomenilo doseženo mejno vrednost letnega vnosa

Sl. 5: Trap-športno strelišče v zaledju izvira Bistrica. (Foto: G. Kovačič)

Fig. 5: Trap-shooting ground in the background of the Bistrica spring. (Photo: G. Kovačič)

svinca v tla. Koliko svinčenih nabojev je bilo v preteklosti izstreljenih, ni moč izračunati, vendar ocene kažejo, da mora biti koncentracija svinca v prsti in verjetno še globlje v notranjosti mnogo višja od mejnih vrednosti, ki jih določa Uredba (UL RS 68/1996). Žal pa se nikoli niso ugotavljale analize vsebnosti svinca v prsti na območju strelišča, ki bi te domneve potrdile. Dosedanje fizikalno-kemijske analize kakovosti vode iz izvira Bistrica tudi ne kažejo na povečano vsebnost svinca v pitni vodi, kar pa ne pomeni, da kontaminacije z njim v prihodnosti ne bo. Svinec je zdravju izredno škodljiva težka kovina, ki se spira zelo počasi. Veliko večje površine je zavzemalo vojaško strelišče, ki je danes že zelo zaraščeno, o količinah vnesenega bakra in svinca v plitko kraško prst pa lahko samo ugibamo.

Turistično naselje Sviščaki

Na Snežniški planoti ni naselja s stalno živečim prebivalstvom, vendar na območju, ki je hidrogeografsko zaledje kraškega izvira Bistrica, so številne planinske in druge koče (prek 20 različnih objektov) ter turistično naselje Sviščaki, ki leži v IV., torej vplivnem vodovarstvenem pasu. Sviščaki so priljubljena izletniška točka in smučarsko rekreacijski center, so pa tudi najpogostejše izhodišče za vzpon na Snežnik. Naselje obsega prek 90 počitniških hišic (Občina Ilirska Bistrica, 2000), mnoge med njimi so zgrajene brez greznic, vprašljiva je tudi vodotesnost greznic pri drugih objektih. Glede na to, da naselje leži na vodooskrbnem območju, bi moralo imeti urejeno kanalizacijo s čistilno napravo.

Promet

Hidrogeografsko zaledje izvira Bistrica je prepredeno s številnimi gozdnimi cestami in vlakami, najpomembnejša pa je cestna povezava od Ilirske Bistrice do Sviščakov. Povprečno letno število vozil na dan je 96 (Gregorc, 1998). Bolj kot število je zaskrbljujoča sestava voznega parka, ki se prevaža po cesti, saj cesta pomeni edino pot za prevoz kamenja iz kamnoloma Gabrovec v spodnji kamnolom, po njej pa vozijo tudi težki tovornjaki za spravilo lesa. Meteorne vode s cestišča spirajo ostanke avtomobilskih gum, olj, ostankov izgorevanja goriv, korozijskih produktov, masti in drugih za vodo škodljivih produktov, ki neprečiščeni odtekajo v vodonosnik (Brenčič & Prestor, 1998). Glede na to, da cesta poteka v neposredni bližini I. vodovarstvenega pasu, bi bilo posledice nesreče praktično nemogoče sanirati, saj bi olje in/ali nafta iz težkih tovornjakov v zelo kratkem času dosegla izvir Bistrica in ga s tem za daljše obdobje onesnažila.

Divja odlagališča odpadkov

Z vidika varovanja pitne vode so zelo problematična divja odlagališča odpadkov, ki se na kraških območjih pojavljajo zlasti kot odlagališča v vrtačah in kot zasmetena brezna in jame (Šebenik, 1994). Brezna so z vodovarstvenega vidika še posebej občutljiva, saj pomenijo neposredno vodno zvezo med površjem in zapletenim sistemom vodnih kanalov v kraškem vodonosniku. Hidrogeografsko zaledje kraškega izvira Bistrica speleološko še ni dobro raziskano.Trenutno je edino znano onesnaženo brezno v zaledju Mrakova jama, ki leži na območju III. vodovarstvenega pasu. Brezno je zasmeteno z raznovrstnim materialom.

Kmetijska in gozdarska dejavnost

Vodooskrbno območje izvira Bistrica označujejo gospodarsko pomembni obsežni jelovo-bukovi gozdovi, v nižjih legah, zlasti na območju I., II., in deloma III. vodovarstvenega pasu, pa tudi borovi gozdovi, ki so se razvili na rendzinah in pokarbonatnih prsteh, ki so z vidika kmetijske rabe primerne le za pašno-košno rabo, usmerjeno v živinorejo (Zadnik *et al.*, 1999). Obdelovalnih površin v napajalnem zaledju z izjemo nekaj ha travnikov ni, veliko več je pašnih površin. Na območju Goljaka nad Zabičami se v IV. vodovarstvenem pasu raztezajo obsežne pašne površine, kjer se poleti pase čreda 170 ovac. Uredba o vnosu nevarnih snovi in rastlinskih hranil v tla (UL RS 68/1996) dovoljuje rejo 3 GVŽ na 1 ha obdelovalne površine, kar pomeni, da število živali na ha obdelovalne površine na Goljaku ne presega mejnih vrednosti letnega vnosa rastlinskih hranil z živalskimi gnojili. Problematične so staje za drobnico, kjer se na gnojišču nabere veliko živalskega gnoja, ki ga deževnica počasi spira v dobro prepustna apnenčasta tla. Na območju II. vodovarstvenega pasu sta še dva manjša pašnika. Na enem se pase približno 8 GVŽ goveda, in sicer samo poleti. Na drugem veliko manjšem pašniku se čez vse leto pase približno 15 glav drobnice. Gre za ekstenzivno pašo, problematična je staja za drobnico, ki leži zelo blizu I. vodovarstvenega pasu izvira Bistrica. V okviru nastajajočega Regijskega parka Snežnik (Uprava RS za varstvo narave in Nizozemsko kraljevo združenje za varstvo narave, 1999) je ozemlje I., II. in velikega dela III. vodovarstvenga pasu izvira Bistrica označeno kot kmetijska krajina, v kateri naj bi se vzpodbujalo ekokmetovanje.

Gozdarska dejavnost je na vodooskrbnem območju izvira Bistrica zelo intenzivna, zlasti pa v III. in IV. vodovarstvenem območju. Z vidika ogrožanja kraške talne vode gozdarstvo ne pomeni večje nevarnosti, problematični so zlasti težka mehanizacija, namenjena spravilu in prevozu lesa, ki je največkrat parkirana kar ob gozdnih cestah po vsej Snežniški planoti, ter odvržene posode, v katerih je bila nekoč nafta, in olje za pogon motornih žag.

UKREPI ZA ZAŠČITO KRAŠKEGA IZVIRA BISTIRCA

Splošni varstveni ukrepi

Za zavarovanje vodnega vira Bistrica pred onesnaževanjem bi morali sprejeti občinski odlok o zavarovanju, ki je bil že obravnavan na občinskem svetu, vendar ni bil sprejet. V odlok bi morali nujno vnesti nekatere spremembe (Tab. 2), zlasti pa bi bilo treba režim v vodovarstvenih pasovih prilagoditi novi metodologiji o zaščiti in varovanju podzemnih voda, ki je bila izdelana v letu 1997 za potrebe Ministrstva za okolje in prostor (Petauer & Veselič, 1997a, 1997b). Pri določanju ukrepov za zaščito vodnega vira sem izhajal iz varstvenih ukrepov v posameznih vodovarstvenih conah, ki ga določa zgoraj omenjena metodologija. Obseg posameznih vodovarstvenih con zaščite kraškega izvira Bistrica je treba sproti prilagajati novim ugotovitvam o hitrosti pretakanja kraške vode v njegovem zaledju, meje vodovarstvenih pasov pa potrditi z izvedbo sledilnih poskusov.

Območje I. in II. vodovarstvenega pasu bi morali označiti s tablami, ki bi opozarjale na posebne vodovarstvene zahteve območja ter ljudi opominjale na nevarnost onesnaženja tako pomembnega vira pitne vode, kot je kraški izvir Bistrica.

Tab. 2: Kratkoročni in dolgoročni ukrepi za zaščito kraškega izvira Bistrica.
Tab. 2: Short- and long-term measures concerning the protection of the Bistrica karst spring.

Kratkoročni ukrepi	Dolgoročni ukrepi
zavarovanje vodnega vira z odlokom	ureditev preostalega dela ceste II. Bistrica-Sviščaki
sanacija spodnjega kamnoloma	graditev kanalizacijskega omrežja in čistilne naprave na Sviščakih
sanacija strelišča Črne njive	ureditev staj za drobnico v skladu s Strokovnim navodilom (UL SRS 10/1985)
očiščenje Mrakove jame	ureditev kamnoloma Gabrovec
ureditev dela ceste II. Bistrica-Sviščaki, da se prepreči odtekanje s cestišča v vodonosnik	
graditev neprepustnih greznic na Sviščakih	
namestitev opozorilnih tabel	

Sanacija kamnolomov

Za preprečitev onesnaževanja izvira Bistrica je potrebna takojšna sanacija spodnjega kamnoloma v II. vodovarstvenem pasu. Po Pravilniku (Petauer & Veselič, 1997b) v II. vodovarstveni coni ni dovoljeno odpiranje kamnolomov, obstoječe pa je treba zapreti in sanirati. Da bi se zmanjšalo tveganje, bi morali zaradi slabega nadzora z uredbo v kamnolomu prepovedati odlaganje odpadnega gradbenega materiala, saj je njegova sestava vprašljiva oziroma bi ga morali strogo nadzorovati. Po Rismalovi metodologiji zaščite podzemnih voda iz leta 1993 (Prestor *et al.,* 1999) je v II. vodovarstvenem pasu prepovedano odlaganje odpadnega gradbenega materiala, po metodologiji iz leta 1997 (Petauer & Veselič, 1997b) pa je dovoljeno pod pogojem, da sestava materiala ni sporna z vidika onesnaževanja pitne vode. Poleg tega bi bilo v kamnolomu treba urediti parkirne prostore za težko mehanizacijo in skladišče za nafto, tako da se prepreči prelivanje nevarnih in strupenih tekočin zunaj urejenih in vodotesnih prostorov, kot to določa Pravilnik (Petauer & Veselič, 1997b). Iz kamnoloma je treba odstraniti tudi vsa neuporabna vozila in delovne stroje. Z vodovarstvenega vidika bi bilo najboljše, če bi kamnolom zasuli in ozelenili. Vendar je treba na sanacijo gledati širše, saj je kamnolom pomemben življenjski prostor za redke vrste ptic. Tako je bil tu prvič v Sloveniji opazovan skalni berglez *(Sitta neumayer)* (Surina, 1999), kot verjetnega gnezdilca pa je isti avtor označil tudi redkega puščavca *(Monticola solitarius).*

Delujoči kamnolom Gabrovec je treba sanirati do stopnje, da obratovanje kamnoloma ne bo ogrožalo kraške talne vode. Zasipavanje in ozelenitev kamnoloma z vodovarstvenega vidika nista sporna, upoštevati pa je treba redke vrste ptic, ki so si našle zatočišče v njegovem skalovju.

Sanacija strelišča na Črnih njivah

Da bi preprečili daljnosežne posledice dolgoletnega vnašanja svinca v občutljivo kraško notranjost na kakovost pitne vode izvira Bistrica, je potrebna sanacija športnega strelišča na Črnih njivah. Količina izstreljenih nabojev na strelišču je zelo velika, kar pomeni, da je tanka kraška prst dobro prepredena s svinčenimi šibrami. Onesnaženo prst je treba z aktivne površine strelišča odstraniti ter jo odložiti na varen prostor zunaj vodovarstvenih območij. Območje strelišča bi nato pokrili z nepropustno folijo, čez pa nasuli novo prst. Prostor bi končno uredili tako, da meteorne vode s strelišča ne bi nekontrolirano odtekale v vodonosnik, kar bi znatno zmanjšalo potencialno nevarnost onesnaženja vodnega vira s težkimi kovinami. Popolno varnost pitne vode v izviru Bistrica bi zagotovili šele s sanacijo obstoječega strelišča ter preselitvijo strelišča na primerno lokacijo zunaj vodovarstvenih območij vodnih virov občine Ilirska Bistrica.

Ureditev turističnega naselja Sviščaki

Pravilnik (Petauer & Veselič, 1997b) določa, da morajo imeti vsa naselja na vodooskrbnih območjih urejeno kanalizacijo, ter dovoljuje graditev novih objektov samo v primeru, če so ti objekti priključeni na kanalizacijsko omrežje in čistilno napravo. Za turistično naselje Sviščaki bi bila zelo primerna postavitev manjše mehansko-biološke čistilne naprave. Graditev kanalizacijskega omrežja in čistilne naprave na Sviščakih predvideva tudi Dologoročni plan občine Ilirska Bistrica za obdobje 1986 do 2000 (UL RS 7/1999). Varnost pitne vode je smiselno zagotavljati z graditvijo neprepustnih greznic in njihovim rednim čiščenjem, z nadzorom nad vodotesnostjo ter z odvozom odpadnega blata, saj do graditve čistilne naprave in kanalizacijskega omrežja še dolgo ne bo prišlo. Greznice bi morale biti urejene tako, da bi vanje odtekala le hišna odpadna voda (to je odpadna voda iz sanitarij in kuhinj), biti pa morajo tudi prezračevane. Padavinske vode ne smejo biti speljane v greznice, praznjenje in vzdrževanje greznic pa mora biti skladno s Strokovnim navodilom o urejanju gnojišč in greznic (UL SRS 10/1985, v nadaljnjem besedilu Strokovno navodilo).

Ureditev cestnega omrežja

Ceste v zaledju je treba urediti do stopnje, da meteorne vode s cestišča ne odtekajo neposredno v vodonosnik, kar je treba najprej urediti na odseku ceste Ilirska Bistrica-Sviščaki v neposredni bližini I. vodovarstvene cone izvira Bistrica. Preostali del ceste je treba urediti tako, da se na minimum zmanjša možnost nesreč z nevarnimi snovmi, kar pomeni, da je treba omejiti hitrost vožnje, vsako razlitje pa takoj sanirati. Opozorilne table o vodovarstvenih območjih bi morali postaviti tudi ob cesti Ilirska Bistrica-Sviščaki, ki bi voznike opozarjale na nevarnosti za vodni vir pri izlitju nevarnih snovi ob avtomobilskih nesrečah.

Sanacija onesnaženega brezna Mrakova jama

Še sprejemljivo količino odpadkov, to je količino, ko so izcedne vode iz odlagališča še pod neko mejo potencialnega ogrožanja kakovosti vodnega vira, je težko določiti (Šebenik, 1994). Zato je smiselna sanacija vseh divjih odlagališč odpadkov na vodooskrbnih območjih kraških izvirov. Za varovanje kakovosti pitne vode v izviru Bistrica je treba brezno Mrakova jama očistiti. Pozornost je potrebno nameniti tudi odkrivanju novih onesnaženih jam in brezen. Na podlagi pokrajinskih značilnosti divjih odlagališč odpadkov (Šebenik, 1994) lahko sklepamo, da teh ni veliko, saj so divja odlagališča odpadkov praviloma zelo blizu naselij in v bližini dostopnih poti, kjer pa ta pojav ni opazen.

Ukrepi v kmetijski in gozdarski dejavnosti

Na vodooskrbnem območju kraškega izvira Bistrica prevladuje ekstenzivno kmetijstvo, kar pomeni, da je v veliki meri skladno z interesi varstva pitne vode. Za povečanje varnosti pred kmetijskim onesnaženjem bi bilo treba v skladu s Strokovnim navodilom (UL SRS 10/1985) primerno urediti gnojišča v stajah z drobnico, tako da izcedne vode iz gnoja ne bi prosto odtekale v vodonosnik.

Pri gozdarski dejavnosti je treba pri uporabi mehanizacije v gozdu paziti, da ne bi prišlo do izlitja olja in naftnih derivatov v tla.

ZAHVALA

Zahvaljujem se Primožu Kovačiču za strokovni prevod povzetka in Boštjanu Surini za tehtne pripombe ob pregledu prispevka.

THE ENVIRONMENTAL VULNERABILITY OF THE BISTRICA KARST SPRING AND SUGGESTED MEASURES FOR ITS PROTECTION

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SUMMARY

The Bistrica karst spring is, due to its landscape characteristics (fissure and karstified aquifer), extremely vulnerable. Its hydrogeological background consists of the vast uninhabited forests of the deep karst Snežnik plateau. The spring is one of the most important drinking water resources in the south-western part of Slovenia and has great potentials. The importance of the spring is intensified by the fact that there is no other adequate drinking-water resource in the wider area of the Ilirska Bistrica Comune that could be used as a substitute spring in the event of contamination. The procedures concerning the protection of the spring are stated in an inadequate act passed by the local community, and none of the water-protection measures have been carried out so far. The analyses of water samples taken from the spring have shown no signs of chemical contamination, although the microbiological quality of the spring is slightly lower than normal. The greatest threats to the spring are sports, construction, tourist and forestry activities taking place in the district, as well as traffic related to them. In order to ensure appropriate quality of the spring drinking water in the future, the following measures should be taken: rehabilitation of the lower quarry and the Črne njive shooting-ground, adequate sanitation for the Sviščaki tourist resort, regulation of the road system in the district of the spring, and a close control over the implementation of preventive measures concerning construction, forestry and farming in the areas in question.

Key words: environmental vulnerability, the Bistrica karst spring, water-protection measures, water-protection areas

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SEXUAL SIZE DIMORPHISM AND LIFE HISTORY TRAITS OF TWO EUROPEAN SPADEFOOT TOADS *(PELOBATES FUSCUS* AND *P. SYRIACUS)* IN ALLOPATRY AND SYMPATRY

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ABSTRACT

We studied the variation in sexual size dimorphism (SSD) and life history traits in two spadefoot toad species (Pelobates fuscus *and* P. syriacus) *across the part of southeastern European geographic distribution (Panonnian Plain and the Balkans), including the area of their sympatry. Species differ considerably in the body size of adult individuals, in the direction and the extent of SSD, while the differences in tadpole and juvenile sizes prior to or after metamorphosis, as well as in longevity and time of attainment of sexual maturity, appeared to be much smaller and without consistent variation pattern. Significant intraspecific variation was found in both species for body size, magnitude of SSD, average longevity and time of sexual maturity attainment. Intraspecific variation in these traits was much more pronounced in* P. syriacus *than in* P. fuscus. *Adult individuals of* P. syriacus *from the zone of strict sympatry were significantly smaller but larger as tadpoles and with the lower level of SSD. Also, these individuals had shorter life span and earlier sexual maturity (at least one year) than conspecific individuals from the geographically remote allopatric part of the species range.*

Key words: spadefoot toads, body size, longevity, sexual maturity, intersex size difference

DIMORFISMO SESSUALE DI TAGLIA E TRATTI EVOLUTIVI DI DUE SPECIE DI ROSPO EUROPEO *(PELOBATES FUSCUS* E *P. SYRIACUS)* IN ALLOPATRIA E SIMPATRIA

SINTESI

Gli autori hanno studiato le variazioni nel dimorfismo sessuale di taglia (SSD) e nei tratti evolutivi di due specie di rospi pelobati (Pelobates fuscus e P. syriacus) *dell'Europa sud-orientale (Pianura Pannonica e Balcani), considerando anche l'area della loro simpatria. Le specie si differenziano considerevolmente per le dimensioni degli individui adulti, che ne caratterizzano, inoltre, il dimorfismo sessuale di taglia. Le differenze riscontrate nelle dimensioni di girini ed individui in stadi giovanili, prima e dopo la metamorfosi, nella longevità e nel tempo di raggiungimento della maturità sessuale, appaiono minori e sprovviste di un modello di variazione consitente. Alcune significanti variazioni intraspecifiche sono state invece riscontrate in entrambe le specie per quanto riguarda le dimensioni corporee, l'ampiezza dell'SSD, la longevità media ed il tempo di raggiungimento della maturità sessuale. Le variazioni intraspecifiche di questi tratti sono risultate più marcate in* P. syriacus *che in* P. fuscus. *Gli individui adulti di* P. syriacus *provenienti dalle zone di simpatria stretta, esattamente come i girini, si sono rivelati significativamente più piccoli ma più tozzi, e con un livello minore di SSD. Questi individui hanno inoltre manifestato una durata della vita inferiore e una maturità sessuale anticipata (di almeno un anno) rispetto ai loro conspecifici provenienti dalla geograficamente distante parte allopatrica dell'estensione della specie.*

Parole chiave: rospi pelobati, dimensioni corporee, longevità, maturità sessuale, differenze intersessuali di dimensioni

INTRODUCTION

The spadefoot toad genus *Pelobates* includes three species in Europe (*P. cultripes, P. fuscus* and *P. syriacus*) and one in extreme northwestern Africa *(P. varaldii)*. Common spadefoot toad, *P. fuscus*, has an extensive range, which covers most of the plains and hilly regions of central, eastern and southeastern Europe (Nollert, 1998). The eastern spadefoot toad, *P. syriacus*, has a contemporary distribution extending from the southern part of the Panonnian Plain and southeastward into Romania, Bulgaria, Greece, and southwestern Asia (Sofianidou, 1997). These species have a narrow zone of sympatry along the lower course of the Danube, as well as further south in the vicinity of the Bosphorus.

The morphology and natural history of the three spadefoot species is quite similar. These amphibians are obligatory subterranean habitat specialists. Typical terrestrial habitats include sandy areas, heathlands and deciduous woodland on light density soils. They actively forage and are opportunistic feeders with a wide trophic niche *(e.g. P. fuscus*; Cogalniceanu *et al.*, 1998). During the day and dry periods they hide in deep burrows. When above ground, during migrations or when searching for food, they are strictly nocturnal. The spawning biotopes include a variety of mostly stagnant, meso- to eutrophic permanent water bodies. It might be that *P. fuscus* and *P. syriacus* differ in their ecological characters as they occur over different geographical ranges - *P. fuscus* has wider latitudinal and narrower altitudinal range than *P. syriacus*. In this regard, sympatric populations on the margins of their range may be non-representative for both species.

Components of life history (principal sources of fitness) represent selective compromises to a suite of environmental variables accumulated over evolutionary time (Wilbur *et al.*, 1974). The assessment of life history traits among closely related species and/or conspecific populations within different habitats and regions should reveal potential sources of life history variation *(e.g.* Tilley & Bernardo, 1993). Also, differences in life history pattern observed in the field may sometimes be attributable to phenotypic or developmental plasticity expressed in response to variation in environmental variables (Stearns, 1992). However, the study of sympatric populations, especially syntopic ones, can potentially remove the obfuscating effects of environment differences. In other words, because two strictly sympatric species share habitat features to a large degree (including the same ponds for breeding in case of amphibians), interspecific differences in life history patterns are probably not due to phenotypic or developmental plasticity expressed in response to differences in environment, except for possible differences in sensitivity to population and predator densities. Foraging mode, phylogenetic inertia and morphological constraints (body size and shape) may also be factors potentially influencing variation of life history traits as in many ectotermic groups (Dunham & Miles, 1985).

For spadefoot toad species, the extent of sexual size differences and life history traits, assessed on a good sample size of a number of populations, are little known. Here we compare life history traits of two spadefoot toads, *P. fuscus* and *P. syriacus* across the Panonnian Plain and the Balkans, which include the area of sympatry with syntopically breeding sites. We were particularly interested in inter- and intraspecific variation in a number of life history characteristics, such as: tadpoles, juveniles and adult body sizes, age of adult individuals and time of attaining sexual maturity, as well as in direction and the extent of sexual size dimorphisms.

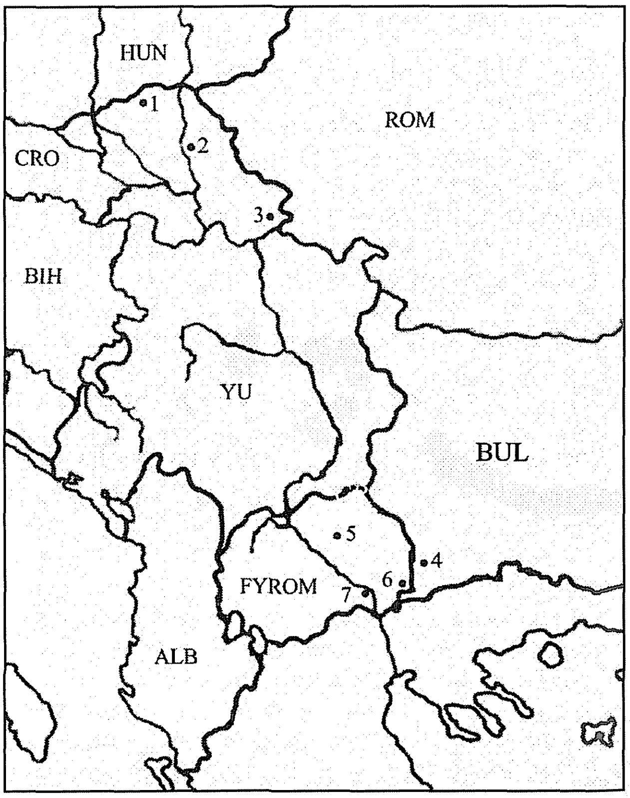

Fig. 1: Distribution of the sampling sites of the spadefoot toads included in the analyses.
Localities: 1 - Cavolj, 2 - Lesino kopovo, 3 - Utrine, 4 - Kresna, 5 - Saramzalino, 6 - Sekirnik, 7 – Prdejci.
Sl. 1: Geografska razporeditev vzorčevalnih mest česnovk, vključenih v analizo.
Lokalitete: 1 - Cavolj, 2 - Lesino kopovo, 3 - Utrine, 4 - Kresna, 5 - Saramzalino, 6 - Sekirnik, 7 – Prdejci.

MATERIAL AND METHODS

Study areas and population samples

As an area where *P. fuscus* lives allopatrically with other spadefoot species, we chose the Subotica-Horgos Sand (Cavolj locality) and the river Tisa inundation area (Lesino kopovo locality, see figure 1). The Deliblato Sand (Utrine locality), situated in the extreme southeastern part of the Panonnial depression, is the area where *P. fuscus* lives in sympatry with *P. syriacus* (Džukić & Pasuljević, 1983). Lesino kopovo lies in an area with quite different geological and edaphic characteristics in comparison to the two Sands. The depression soil of the area is salt-affected and may be regarded as solonetz type according to edaphic classification (Nejgebauer *et al.*, 1959). Allopatric *P. syriacus* populations, from which samples were taken, came from Bulgaria (one breeding unit) and the Former Yugoslav Republic of Macedonia, FYROM (three breeding units, Fig. 1). Locality position data (UTM code, longitude, latitude, altitude) as well as sample sites of tadpoles (at the stage 39; Gosner, 1960), juveniles (just after the metamorphosis) and of sexually matured individuals are presented in table 1. In order to obtain an adequate number of adult individuals of allopatric *P. syriacus*, we pooled individuals collected from these localities neglecting possible population effect on the studied characters' variabilities.

The specimens used in this study are housed in the Georg Džukić's batrachological collection (Institute for Biological Research, Belgrade) and in the collection of the Macedonian Museum of Natural History, Skopje, FYROM.

Morphometrics

Individuals were weighed to the nearest 0.01 g. Nineteen morphometric measurements were taken on each adult specimen's right side using digital caliper (to the nearest 0.01 mm): L - total body length (measured from the snout to cloaca), F – femur length (from the cloaca to the distal end of femur measured on bent hindlimb), T – tibia length, P - pes length (measured from the metatarsal wrist to the apex of the longest, fourth, toe), Lpa - forelimb length (humerus length + length from the proximal articulation of humerus to the apex of the longest, 3rd finger), Lpp - hindlimb length (foot length to the apex of the longest toe, the 4th one), DpPa - length of forelimb first toe (from the proximal end of tubercle to the apex of the 1st finger), DsPa - forelimb second finger length (from the proximal end of tubercle to the apex of the 2nd finger), DpPp - length of hindlimb first toe (from the distal end of inner metatarsal tubercle to the apex of the toe), Cint - inner metatarsal tubercle length, Lc - head length (snout to mouth corner), Ltc - head width (between mouth corners), Spp - minimum interorbital space, Spi - minimum internarial space, Spcr - intercanthal distance, Lo - eye length, Ltp - upper eyelid width, Dro - snout to eye distance, Dno - nostrils to anterior eyelid commisure. Tadpoles and juveniles were measured for the total body length only (from the snout to the tail's tip for tadpoles and from the snout to cloaca for juveniles).

Tab. 1: Locality position data (UTM code, longitude, latitude, altitude) and sample sizes.
Localities: 1 – Cavolj, 2 – Lesino kopovo, 3 – Utrine, 4 – Kresna, 5 – Saramzalino, 6 – Sekirnik, 7 – Prdejci
Tab. 1: Lokaliteta (UTM, zemljepisna dolžina in širina, nadmorska višina) in velikost vzorcev.
Lokalitete: 1 – Cavolj, 2 – Lesino kopovo, 3 – Utrine, 4 – Kresna, 5 – Saramzalino, 6 – Sekirnik, 7 – Prdejci

	1	2	3	4	5	6	7
UTM code	CS91	EQ26	EQ26	FM81	EM72	FL58	FI26
Longitude	46°10'	44°50'	44°50'	41°43'	41°47'	41°26'	41°12'
Latitude	19°40'	21°18'	21°18'	23°9'	21°57'	22°48'	22°31'
Altitude (m)	100	80	95	180	280	210	65
P. fuscus							
Adults - females	8	27	26	-	-	-	-
Adults - males	39	16	5	-	-	-	-
tadpoles	20	-	8	-	-	-	-
juveniles	17	-	14	-	-	-	-
P. syriacus							
Adults - females	-	-	30	4	1	2	4
Adults - males	-	-	21	14	2	1	2
tadpoles	-	-	10	-	-	-	10
juveniles	-	-	15	-	-	-	10

Age and time of sexual maturation

Individual ages were assessed by skeletochronology. A general description of this histological method can be found elsewhere (*e.g.* Castanet *et al.*, 1993). Frozen sections of the demineralized bones were cut at 16 µm and stained in Ehrlich's hematoxylin. Second phalange's diaphyseal portion of the forelimb's third digit was used for counting the lines of arrested growth (LAG), which corresponded to annual resting growth periods. A comparison of the number of LAGs in the phalanges and in the femur of the same individuals (three toads of both species) revealed the same LAG numbers. We managed to assess an individual onset of sexual maturity as a sudden decrease in bone growth and concomitant rapprochement of LAGs (see Kleinenberg & Smirina, 1969; Francillon-Vieillot *et al.*, 1990). Possible resorption of the first LAG, due to endosteal cavity growth, was taken into account when age was estimated, and one year added to the estimated age when resorption was obvious.

Statistical analyses

Various parametric and nonparametric tests were used to analyze data. One way ANOVA was used to analyze differences in body weight and morphometric traits between species and between sexes. Mahalanobis distances were calculated to measure overall morphometric differences between genders using the set of all 19 characteristics. A non-parametric Mann-Whitney U test described differences in age and time of attaining sexual maturity, while frequency distributions of age classes in females and males were tested by the Kolmogorov-Smirnov test. We used the Tukey-Kramer test for multiple comparisons among means. Correlations between morphometric traits and between body measures and age were analyzed by the Spearman correlation test (Rs).

All statistical analyses were performed using various STATISTICA program procedures.

RESULTS

Body size measures - intersexual and interlocality comparisons

Descriptive statistics of adult body measures are presented for both species (Tabs. 2a-2e). Intersexual differences between *P. fuscus* toads from Cavolj and Utrine, but not from the Lesino kopovo locality, were significant in respect to almost all analyzed characteristics. Females were significantly larger than males, being apparently twice as massive. Among morphometric traits only toe lengths did not differ significantly between sexes. Males from Cavolj showed significantly larger values only for eye-length (ANOVA, $p < 0.001$) and interorbital distance (ANOVA, $p < 0.05$). In the Utrine population, even these measurements were not significantly larger in males. Mahalanobis distance between sexes in *P. fuscus* from Cavolj was estimated to be $D^2 = 20.23$ ($p < 0.001$), and from the Lesino kopovo locality $D^2 = 12.92$ ($p < 0.01$). This measure was not computed for the Utrine population due to the small sample size of males. Males and females from Lesino kopovo locality were very similar in respect to age at maturity and age range and therefore presented a good sample for analyses. Interestingly, intersexual differences were not significant, except that females were more massive and had longer femurs.

Sexual dimorphism in the common spadefoot toad was seen, not only in overall body-size, but also in specific morphological characters such as limbs. Elongated fore- and hindlimbs in males can be regarded as characters that are favored in male-male competition for females and such sexual dimorphism has been found for some anuran species (Halliday & Tejedo, 1995), but the fight between *Pelobates* males (paired-unpaired) has not been documented yet (Eggert, *pers. comm.).* Much larger fore- and hindlimbs in males than in females, relative to body length, were confirmed for the common spadefoot toad from Cavolj (Lpa/L, $p < 0.05$; Lpp/L, $p < 0.01$). Also, Cint/L index (inner metatarsal tubercle length/body length) appeared to be significantly larger in males compared to females (ANOVA, $p < 0.001$). However, such sexual dimorphism was not found in the other two population samples, Utrine and Lesino kopovo.

Interpopulation comparisons between *P. fuscus* samples revealed that individuals from Utrine and Cavolj did not differ statistically in respect to most morphometric traits, but in a few cases differences were apparent. Notably, hind limbs and head dimensions were significantly larger in males from Cavolj (ANOVA, $p < 0.05$), while females from the same population were smaller than their counterparts from Utrine in respect to all traits that showed significant differences; *i.e.* hind limbs, inner metatarsal tubercle, eye-length and interorbital distance. However, when samples from Cavolj and Lesino kopovo were compared, significant differences appeared in almost all characters (ANOVA, $p < 0.001$), individuals of both genders from Cavolj being larger. Differences were not significant only for total body length and intercanthal distance in males and for intercanthal distance and minimum interorbital space in females. Utrine *vs.* Lesino kopovo comparison revealed significant differences only in females (in all characters except for minimum interorbital space and eye length), with Lesino kopovo individuals being smallest in comparison to the other two populations.

P. syriacus from Utrine did not show any intersexual differences in morphometric characters. Mahalanobis distance between sexes in *P. syriacus* from this population was estimated to be $D^2 = 9.758$ ($p > 0.05$). Neither females nor males of this species differed significantly in hindlimb lengths and the size of metatarsal tubercle relative to body size (ANOVA, $p > 0.05$). However, forelimbs were much larger in males in comparison to females (ANOVA, $p < 0.001$). Contrary, intersexual differences in allopatric *P. syriacus* individuals from FYROM+Bulgaria were statistically significant in respect to all analyzed traits. Males appeared to be larger than females. The most prominent differences were in weight, body length, fore- and hindlimbs and toe length (ANOVA, $p < 0.001$). Mahalanobis distance between the sexes of *P. syriacus* from this sample was significant ($D^2 = 41.22$, $p < 0.05$). Elongated fore- and hindlimbs in males vs. females appeared to be statistically significant (ANOVA: Lpa/L, $p < 0.05$; Lpp/L, $p < 0.01$), but the size of metatarsal tubercle relative to body size failed to show dimorphism (ANOVA, $p > 0.05$). Males being larger than females is a very interesting result for it is not common in amphibians. Yet, both male and female samples lack young adults (Fig. 3) and the individuals that we compared might have been close to the maximum size they would reach.

Interpopulation comparison within the eastern spadefoot revealed that allopatric females and males (FYROM + Bulgaria) were significantly larger than individuals living in sympatry with the common spadefoot (Utrine) for most morphometric traits in females (except in nostrils to anterior eyelid commisure distance) and all traits in males with the most prominent differences being in total body length and weight (ANOVA, $p < 0.001$). Again, in allopatric population both male and female samples lack young adults and the differences in body sizes could be due to differences in age classes in samples compared, and not to presumable allopatry/sympatry differences.

Tab. 2a: Differences in morphometric characters between sexes in *Pelobates syriacus* ***from Utrine locality.***
X - mean value, SD - standard deviation, SSD - female/male size ratio values. Symbols (* P<0.05; ** P<0.01; *** P<0.001; n.s. - non significant) denote the significance level of SSD, obtained by ANOVA test.
Tab. 2a: Morfometrične razlike med spoloma *Pelobates syriacus* ***z lokalitete v Utrinah.***
X - srednja vrednost, SD - standardni odklon, SSD (VRS) je velikostno razmerje med spoloma. Simboli (* P<0,05; ** P<0,01; *** P<0,001; n.s. – ni signifikantno) ponazarjajo interval zaupanja SSD, dobljen s testom ANOVA.

	Pelobates syriacus **(Utrine)**					
	Males (N=21)		Females (N=30)			
Variable	X ± SD	range	X ± SD	range	SSD	signif.
Weight	28.91 ± 13.49	10.26-60.76	32.01 ± 15.68	11.63-71.92	1.15	n.s.
L	61.13 ± 8.97	47.55-75.62	60.83 ± 8.93	47.84-79.56	1.00	n.s.
F	28.90 ± 4.92	20.47-37.81	29.27 ± 4.75	22.47-40.47	1.01	n.s.
T	23.86 ± 3.60	18.54-32.45	23.77 ± 3.13	17.84-32.54	1.00	n.s.
P	30.63 ± 5.04	22.64-38.44	28.15 ± 4.65	18.51-37.39	0.92	n.s.
Lpa	41.65 ± 8.47	30.90-58.18	38.85 ± 6.41	28.20-53.04	0.93	n.s.
Lpp	93.52 ± 14.95	67.81-121.91	92.96 ± 13.21	73.63-128.22	0.99	n.s.
DpPa	10.24 ± 1.57	7.66-12.81	9.99 ± 1.59	7.22-14.33	0.98	n.s.
DsPa	8.92 ± 1.76	6.12-12.43	8.61 ± 1.66	6.40-13.09	0.97	n.s.
DpPp	5.69 ± 1.25	3.65-8.12	5.41 ± 0.95	3.56-7.80	0.95	n.s.
Cint	5.78 ± 0.97	4.40-7.53	5.73 ± 1.12	4.12-8.24	0.99	n.s.
Lc	16.47 ± 2.92	12.30-20.37	16.44 ± 2.62	11.24-23.62	1.00	n.s.
Ltc	20.01 ± 3.83	14.46-26.55	19.42 ± 2.73	14.53-30.76	0.97	n.s.
Spp	7.26 ± 1.10	4.76-9.81	7.30 ± 1.03	4.78-9.67	1.01	n.s.
Spi	4.38 ± 0.70	3.49-5.89	4.67 ± 0.68	3.46-6.44	1.07	n.s.
Spcr	8.72 ± 1.02	6.64-11.08	8.93 ± 1.21	6.34-11.26	1.02	n.s.
Lo	6.62 ± 0.91	5.01-8.40	6.81 ± 0.87	4.98-8.88	1.03	n.s.
Ltp	5.30 ± 0.54	4.60-6.37	5.04 ± 0.79	2.77-6.79	0.95	n.s.
Dro	9.42 ± 1.28	7.42-11.33	9.62 ± 1.37	6.65-12.79	1.02	n.s.
Dno	5.84 ± 1.01	4.30-7.64	5.94 ± 0.73	4.48-9.30	1.02	n.s.

Tab. 2b: Differences in morphometric characters between sexes in* Pelobates syriacus *from FYROM & Bulgaria localities (for legend see table 2a).

Tab. 2b: Morfometrične razlike med spoloma* Pelobates syriacus *z lokalitet v Makedoniji in Bolgariji (legenda: glej tabelo 2a).

***Pelobates syriacus* (FYROM & Bulgaria)**						
	Males (N=19)		Females (N=11)			
Variable	X ± SD	range	X ± SD	range	SSD	signif.
Weight	53.89 ± 6.44	43.28-66.81	44.80 ± 6.39	35.15-56.35	0.81	***
L	75.81 ± 3.06	68.75-79.73	70.51 ± 4.08	66.14-79.34	0.93	***
F	36.53 ± 1.87	31.48-39.73	33.24 ± 2.31	29.74-36.93	0.91	***
T	29.90 ± 1.35	27.31-33.46	27.71 ± 1.91	24.24-30.25	0.93	**
P	42.01 ± 2.36	37.07-46.09	36.47 ± 2.77	31.48-40.47	0.87	***
Lpa	55.60 ± 2.43	50.46-59.77	48.91 ± 5.39	42.49-62.77	0.88	***
Lpp	120.45 ± 5.55	106.09-130.43	107.64 ± 6.81	97.27-117.83	0.89	***
DpPa	15.09 ± 1.01	13.21-16.53	12.53 ± 1.60	8.34-14.55	0.83	***
DsPa	15.63 ± 0.82	13.51-16.53	13.68 ± 0.87	12.12-14.88	0.88	***
DpPp	16.10 ± 1.14	13.54-17.60	15.40 ± 1.11	13.75-17.17	0.96	n.s.
Cint	7.08 ± 0.44	6.17-7.72	6.74 ± 0.55	5.67-7.71	0.95	n.s.
Lc	25.06 ± 0.99	23.34-27.61	23.25 ± 1.31	21.86-25.91	0.93	***
Ltc	29.72 ± 1.77	25.10-32.03	28.09 ± 1.62	25.90-30.73	0.95	*
Spp	8.18 ± 0.77	6.36-9.74	8.10 ± 1.06	6.36-10.37	0.99	n.s.
Spi	6.47 ± 0.45	5.48-7.19	5.99 ± 0.47	5.31-6.76	0.93	**
Spcr	10.90 ± 0.72	9.58-12.54	10.77 ± 1.06	8.86-12.45	0.99	n.s.
Lo	9.05 ± 0.51	8.03-9.90	8.44 ± 0.57	7.78-9.59	0.93	**
Ltp	6.23 ± 0.28	5.62-6.70	6.02 ± 0.26	5.67-6.50	0.97	n.s.
Dro	11.82 ± 0.60	10.55-12.74	11.10 ± 0.50	10.41-11.78	0.94	**
Dno	6.73 ± 0.52	5.57-7.64	6.34 ± 0.37	5.70-6.73	0.94	*

Tab. 2c: Differences in morphometric characters between sexes in* Pelobates fuscus *from Utrine locality (for legend see table 2a).

Tab. 2c: Morfometrične razlike med spoloma* Pelobates fuscus *z lokalitete v Utrinah (legenda: glej tabelo 2a).

***Pelobates fuscus* (Utrine)**						
	Males (N=5)		Females (N=26)			
Variable	X ± SD	range	X ± SD	range	SSD	signif.
Weight	10.37 ± 1.18	8.73-12.06	17.18 ± 6.45	10.22-32.95	1.66	*
L	44.79 ± 2.77	41.21-48.08	53.71 ± 5.22	46.45-65.16	1.20	***
F	20.46 ± 1.35	18.99-22.30	23.44 ± 2.56	19.34-27.95	1.15	**
T	16.65 ± 0.98	15.24-17.79	20.00 ± 1.90	16.50-24.64	1.20	***
P	20.24 ± 1.44	18.45-22.21	24.65 ± 3.02	19.46-31.92	1.22	****
Lpa	30.39 ± 2.42	27.61-33.89	35.01 ± 3.39	28.54-40.96	1.15	*
Lpp	66.05 ± 3.48	62.01-71.46	75.53 ± 7.47	66.47-92.02	1.14	n.s.
DpPa	7.70 ± 1.01	6.43-9.12	8.75 ± 1.16	6.55-11.99	1.14	n.s.
DsPa	6.70 ± 1.17	5.66-8.17	7.94 ± 1.27	5.11-10.63	1.19	n.s.
DpPp	4.10 ± 0.34	3.80-4.56	4.24 ± 0.59	3.33-5.58	1.03	n.s.
Cint	4.02 ± 0.31	3.69-4.50	4.75 ± 0.57	3.67-6.04	1.18	*
Lc	11.95 ± 0.92	12.75-0.92	14.66 ± 1.37	11.22-18.65	1.23	***
Ltc	14.40 ± 1.79	12.10-17.11	18.66 ± 2.37	14.65-24.26	1.30	***
Spp	5.48 ± 0.48	4.77-6.02	5.84 ± 0.75	4.42-7.60	1.07	n.s.
Spi	3.92 ± 0.37	3.28-4.24	4.57 ± 0.69	3.52-6.31	1.17	n.s.
Spcr	6.16 ± 0.86	5.20-7.42	7.26 ± 0.75	6.14-9.20	1.18	**
Lo	5.30 ± 0.55	4.80-6.07	5.04 ± 0.81	3.99-6.75	0.95	n.s.
Ltp	3.86 ± 0.43	3.27-4.20	4.51 ± 0.44	3.64-5.36	1.17	**
Dro	6.85 ± 0.59	6.02-7.63	8.03 ± 0.94	6.22-10.11	1.17	*
Dno	3.88 ± 0.44	3.24-4.30	4.68 ± 0.65	3.02-5.62	1.21	*

Tab. 2d: Differences in morphometric characters between sexes in** Pelobates fuscus **from Cavolj locality (for legend see table 2a).

Tab. 2d: Morfometrične razlike med spoloma** Pelobates fuscus **z lokalitete v Cavolju (legenda: glej tabelo 2a).

Pelobates fuscus **(Cavolj)**						
	Males (N=39)		Females (N=28)			
Variable	X ± SD	range	X ± SD	range	SSD	signif.
Weight	12.54 ± 2.69	7.79-18.57	19.14 ± 5.82	8.87-32.49	1.53	***
L	46.00 ± 3.12	40.57-56.65	54.02 ± 4.46	47.07-62.15	1.17	***
F	22.76 ± 2.09	16.44-25.67	23.99 ± 2.15	20.15-30.57	1.05	*
T	18.61 ± 1.25	16.19-20.79	19.95 ± 1.70	16.10-23.29	1.07	***
P	23.66 ± 1.67	20.03-26.18	28.73 ± 4.19	21.89-36.19	1.21	***
Lpa	31.98 ± 3.88	13.60-37.85	34.51 ± 3.45	28.22-41.48	1.08	**
Lpp	74.12 ± 4.67	63.16-83.66	73.40 ± 9.21	59.07-90.18	0.99	n.s.
DpPa	8.13 ± 0.86	6.01-9.56	7.89 ± 0.88	6.52-9.77	0.97	n.s.
DsPa	6.76 ± 0.62	5.50-8.07	7.24 ± 0.98	5.83-9.27	1.07	*
DpPp	4.40 ± 0.55	3.26-5.72	4.62 ± 0.70	3.51-6.13	1.05	n.s.
Cint	4.24 ± 0.35	3.19-5.12	4.36 ± 0.50	3.30-5.68	1.03	n.s.
Lc	12.88 ± 1.05	11.04-15.96	14.07 ± 1.20	11.80-17.20	1.09	***
Ltc	15.72 ± 1.86	12.61-20.30	18.86 ± 1.78	14.66-22.01	1.20	***
Spp	5.81 ± 0.54	4.90-6.79	5.53 ± 0.55	4.50-6.67	0.95	*
Spi	4.43 ± 0.48	3.17-5.95	4.63 ± 0.71	3.29-6.27	1.05	n.s.
Spcr	7.07 ± 0.57	5.99-8.15	7.64 ± 0.60	6.63-8.79	1.08	***
Lo	5.42 ± 0.77	3.81-6.67	4.34 ± 1.04	3.25-7.47	0.80	***
Ltp	3.81 ± 0.52	2.63-5.13	4.28 ± 0.56	3.27-5.96	1.12	***
Dro	7.37 ± 0.76	6.24-9.33	8.19 ± 0.77	6.96-9.99	1.11	***
Dno	4.31 ± 0.55	3.51-6.27	4.7 ± 0.50	3.68-6.18	1.09	**

Comparisons between species from the zone of sympatry (Utrine) revealed statistically significant differences in almost all analyzed traits. Both males and females of *P. syriacus* were significantly larger than their *P. fuscus* counterparts (ANOVA, at least at $p < 0.05$). On average, the largest tadpoles and juveniles were those of *P. fuscus* from the zone of sympatry (Utrine) and the smallest ones were preadult individuals of the same species from the zone of allopatry (Cavolj, Tab. 3).

We only compared tadpoles and juveniles from the same locality, since it is known that tadpole size in anurans is strongly related to tadpole density and the amount of food available in the pond. Interspecific differences (Utrine locality) were not statistically significant neither in tadpoles nor in juveniles (ANOVA, $p>0.05$). *P. fuscus* juveniles reached on average only 35.7% (Cavolj) and 33.8% (Utrine) of the tadpole size prior to metamorphosis, while in *P. syriacus* populations figures were 34.9% (FYROM) and 35.2% (Utrine). It was also interesting to compare juvenile with the adult body size. On average, *P. fuscus* juveniles were from 58.1% (Cavolj) to 61.0% (Utrine) of adult females, and from 68.5% (Cavolj) to 73.2% (Utrine) of adult male body size. In *P. syriacus*, on average, juveniles reached 53.1% of adult female body size in Utrine population and 43.9% of female body size in the FYROM+Bulgaria population.

Age and time at sexual maturation

The life span of adult spadefoot toad species studied ranged from 3 to 16 yr. in *P. fuscus*, and from 2 to 16 yr. in *P. syriacus* species (Tab. 4). Such an old individuals in both species has not been recorded so far. Biegler (1966) noticed an 11 years old *P. fuscus* in captivity, while Eggert & Guyetant (1999) and Wiener (1997) reported 9 years old individuals in the field. On average, the oldest were males of the common spadefoot from Cavolj locality (10.21 ± 2.73 yr.), while the youngest were females of the eastern spadefoot from Utrine (4.59 ± 1.56 yr.). Distributions of age classes are given in figures 2 and 3. Differences between genders within locality, as well as differences between localities within sex appeared to be insignificant except in few cases. Males from Cavolj were significantly older then males from Lesino kopovo (Mann-Whitney U test, $p < 0.05$), and males from Utrine locality ($p < 0.01$). Also, intersexual difference in age was significant in the Utrine population sample (females were older than males, Mann-Whitney U test, $p < 0.05$). However, as we managed to score age for only four Utrine males, these differences should be taken with caution. If we exclude an exceptionally old male of 16 yr. from the Utrine sample of *P. syriacus*, even nine years older than the oldest other males, difference between genders in this population appeared insignificant.

Tab. 2e: Differences in morphometric characters between sexes in** Pelobates fuscus **from Lesino kopovo locality (for legend see table 2a).

Tab. 2e: Morfometrične razlike med spoloma** Pelobates fuscus **z lokalitete Lesino kopovo (legenda: glej tabelo 2a).

***Pelobates fuscus* (Lesino kopovo)**						
	Males (N=16)		Females (N=27)			
Variable	X ± SD	range	X ± SD	Range	SSD	signif.
Weight	8.43 ± 3.10	4.00-14.83	12.81 ± 4.37	4.50-24.01	1.52	**
L	43.93 ± 3.89	36.36-49.51	45.38 ± 9.17	41.40-57.94	1.03	n.s.
F	18.63 ± 3.16	14.41-23.13	20.79 ± 3.18	12.46-26.19	1.12	*
T	17.23 ± 1.76	14.12-20.16	18.20 ± 1.77	13.87-21.85	1.06	n.s.
P	20.59 ± 2.33	16.98-24.92	21.55 ± 2.56	16.25-25.14	1.05	n.s.
Lpa	29.25 ± 3.71	22.67-36.56	29.77 ± 3.65	22.43-38.64	1.01	n.s.
Lpp	63.55 ± 6.79	51.42-72.46	68.20 ± 7.87	49.02-82.09	1.07	n.s.
DpPa	6.93 ± 0.71	5.83-8.62	7.24 ± 0.95	4.54-9.25	1.04	n.s.
DsPa	5.88 ± 0.87	4.47-7.38	6.23 ± 0.97	4.32-9.11	1.06	n.s.
DpPp	3.46 ± 0.50	2.62-4.16	3.46 ± 0.43	2.80-4.31	1.00	n.s.
Cint	4.02 ± 0.61	3.15-5.05	4.35 ± 0.65	2.92-5.67	1.08	n.s.
Lc	11.85 ± 1.52	9.57-15.14	12.63 ± 1.48	9.85-14.94	1.07	n.s.
Ltc	14.68 ± 2.16	11.93-18.32	15.37 ± 3.75	10.18-19.95	1.05	n.s.
Spp	5.27 ± 0.47	4.53-6.12	5.74 ± 0.57	4.48-7.04	1.09	**
Spi	4.00 ± 0.54	3.24-5.10	3.98 ± 0.52	2.66-4.86	1.00	n.s.
Spcr	6.09 ± 0.89	4.74-7.55	6.87 ± 0.67	5.17-8.05	1.13	**
Lo	5.23 ± 0.83	3.82-6.52	5.05 ± 0.90	3.40-6.69	0.97	n.s.
Ltp	3.44 ± 0.33	2.88-4.15	3.69 ± 0.52	2.91-5.15	1.07	n.s.
Dro	7.09 ± 0.69	6.04-8.13	6.67 ± 0.78	3.58-7.62	0.94	n.s.
Dno	4.16 ± 0.39	3.56-4.84	4.36 ± 0.37	3.72-5.02	1.05	n.s.

The average life spans of females and males of the other *P. syriacus* sample (FYROM+Bulgaria) were also very similar in spite of the presence of an exceptionally old female of 15 years. Intraspecific difference in age between allopatric and sympatric individuals was statistically significant for both sexes (Mann-Whitney U test, $p < 0.01$). Individuals from Utrine were much younger than spadefoot toads from the southern part of the species range (FYROM+Bulgaria, Tab. 4). Frequency distributions of age classes in females and males were similar in *P. fuscus,* regardless of population, and in *P. syriacus* (Kolmogorov-Smirnov test, $p > 0.05$).

The common spadefoot toads reached sexual maturity at the age of two to five years, while those of eastern spadefoot species at the age of two to four years (Tab. 5). Intersexual differences in this life history trait were negligible in both species (Mann-Whitney U test, $p < 0.05$). Still, male sample from Cavolj lacks young adults (younger than 6 years) which may not allow to obtain accurate results when compared with female sample from the same locality (our analysis shows that both sexes matured at the same age). Also, our male sample from Utrine was not large enough, so these results should not be taken as definite ones. However, within-species variation existed. Thus, both genders of the Cavolj population matured earlier than individuals from Lesino kopovo (Mann-Whitney U test, $p < 0.05$), while males from Utrine locality matured much earlier than males from Lesino kopovo (Mann-Whitney U test, $p < 0.05$). The eastern spadefoot toads of both genders from FYR Macedonia and Bulgaria attained sexual maturity significantly later than individuals from Utrine population (Mann-Whitney U test, $p < 0.001$).

Comparison between spadefoot toads from the zone of sympatry (Utrine) revealed that *P. fuscus* females had a significantly longer life span and they matured later than *P. syriacus* of the same gender (see Tabs. 4 and 5; Mann-Whitney U test, $p < 0.001$ and $p < 0.05$, respectively). On the contrary, *P. syriacus* males were older and they attained sexual maturity later than *P. fuscus* ones (Mann-Whitney U test, $p < 0.001$ and $p < 0.05$, respectively).

Relation between age and size

None of the morphometric characters in the analyzed samples showed significant correlation with age (Rs test, $p > 0.05$). From our data, we concluded that body length is a poor predictor of age as there is considerable size variability observed within most age-classes. For example, 10 years old males of the common spadefoot toad from Cavolj can be as large as 40 to 56 mm, or females of that age from Lesino kopovo range in size from 42 to 65 mm (Fig. 2). Among the eastern spadefoot toads females in the fourth year of age varied in size from 50 to 77 mm (Fig. 3). One should bear in mind that anuran growth generally follows Von Bertalanffy curve, that is, growth is faster at earlier stages than after reaching sexual maturity. After sexual maturation annual growth rate will strongly decrease and become quite low. But, young adults are smaller than old adults because growth does not stop at sexual maturity, but only decreases rapidly.

Tab. 3: Ranges, mean (X) and standard deviations (SD) for body length (mm) in analyzed tadpole and juvenile spadefoot toad samples.
Tab. 3: Razpon, srednje vrednosti (X) in standardni odkloni (SD) v dolžini telesa (mm) pri analiziranih paglavcih in mladostnih osebkih česnovk.

	Tadpoles			**Juveniles**		
sample	N	X±SD	range	N	X±SD	range
	Pelobates fuscus					
Utrine	8	96.89±9.06	80.93-113.16	14	32.74±3.08	27.38-36.64
Cavolj	20	84.61±6.99	70.42-96.19	17	30.26±1.46	27.97-34.01
	Pelobates syriacus					
Utrine	10	91.50±8.54	79.93-104.71	15	32.16±3.41	26.30-37.90
FYROM	10	88.74±15.25	60.63-108.18	10	30.94±1.78	28.18-33.44

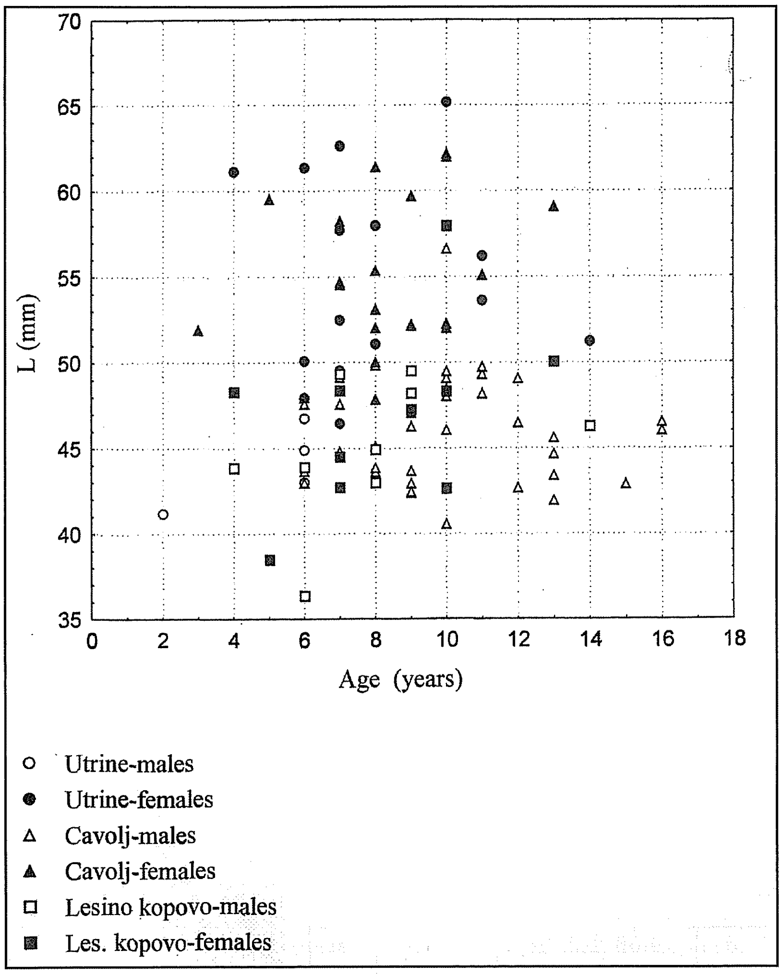

Fig. 2: Distribution of body size (L) and age in the adult *Pelobates fuscus* ***individuals.***
Sl. 2: Velikostna (L) in starostna razporeditev pri odraslih osebkih *Pelobates fuscus.*

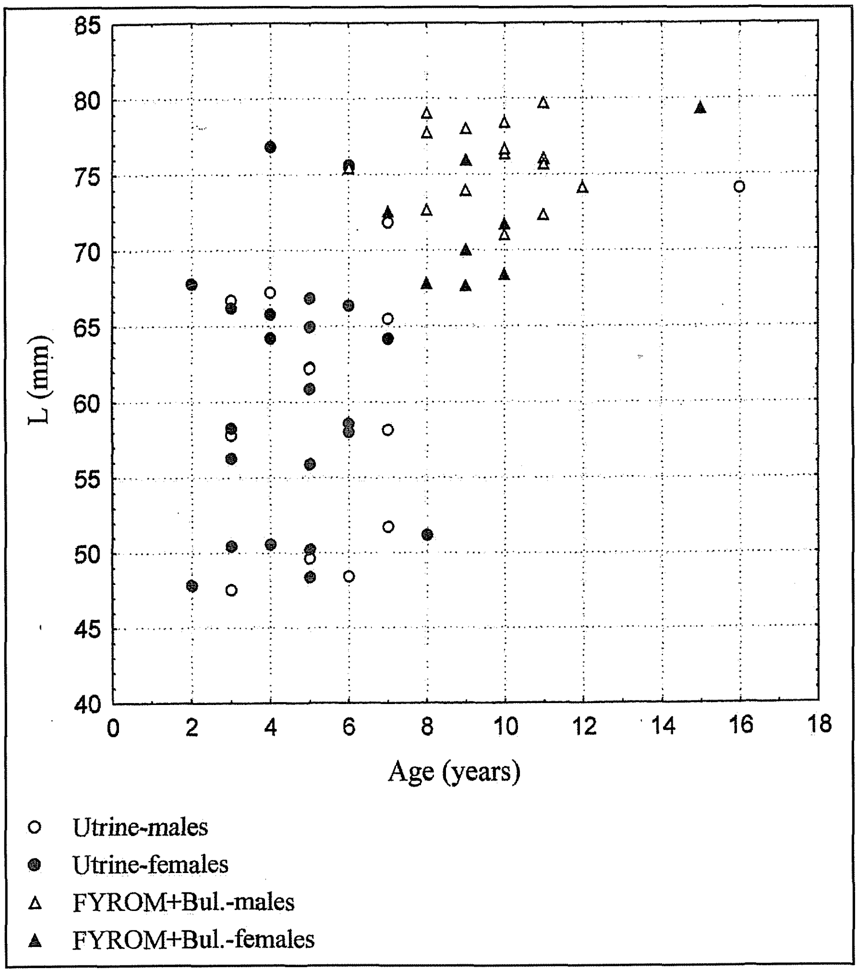

Fig. 3: Distribution of body size (L) and age in the adult* Pelobates syriacus *individuals.
***Sl. 3: Velikostna (L) in starostna razporeditev pri odraslih osebkih* Pelobates syriacus.**

Tab. 4: Descriptive statistics for the age in* Pelobates fuscus *and* Pelobates syriacus *samples (for legend see table 2a).
Tab. 4: Opisna statistika za starost osebkov* Pelobates fuscus *in* Pelobates syriacus *(legenda: glej tabelo 2a).

	Females			Males			
sample	N	X ± SD	range	N	X ± SD	range	sign.
Pelobates fuscus							
Utrine	15	7.93 ± 2.55	4 -14	4	5.00 ± 2.00	2-6	*
Cavolj	22	8.32 ± 2.10	3 -13	37	10.21 ± 2.73	6-16	n.s.
Lesino kopovo	11	8.00 ± 2.64	4 -13	9	7.89 ± 2.80	4-14	n.s.
Pelobates syriacus							
Utrine	22	4.59 ± 1.56	2 - 8	14	6.00 ± 3.26	3-16	n.s.
FYROM & Bul. Macedonia	8	9.63 ± 2.39	7 -15	16	9.38 ± 1.78	6-12	n.s.

Tab. 5: Descriptive statistics for the time of attaining sexual maturity in *Pelobates fuscus* ***and*** *Pelobates syriacus* ***samples (for legend see table 2a).***

Tab. 5: Opisna statistika za starost, ko osebki *Pelobates fuscus* ***in*** *Pelobates syriacus* ***dosežejo spolno zrelost. (legenda: glej tabelo 2a).***

	Females			Males			
sample	N	X ± SD	range	N	X ± SD	range	sign.
Pelobates fuscus							
Utrine	11	3.27 ± 0.79	2 - 4	2	2.00 ± 0.00	2 - 2	n.s.
Cavolj	12	2.75 ± 0.62	2 - 4	18	2.78 ± 0.55	2 – 4	n.s.
Lesino kopovo	10	3.60 ± 0.84	2 - 5	6	3.50 ± 0.84	3 - 5	n.s.
Pelobates syriacus							
Utrine	10	2.30 ± 0.49	2 - 3	9	2.67 ± 0.50	2 - 3	n.s.
FYROM & Bulgaria	4	3.50 ± 0.58	3 - 4	10	3.10 ± 0.52	3 - 4	n.s.

Apparently, spadefoot toads are among many tailless amphibians where body size is strongly influenced by juvenile growth rate followed by a reduction in somatic growth after sexual maturation (Halliday & Verrell, 1988; Platz & Lothrop, 1993; Hota, 1994). A sudden decrease in bone growth and concomitant rapprochement of LAGs in *P. fuscus* and *P. syriacus* was obvious in approximately 56% of the individuals studied. In other individuals the absence of such a pattern was probably due to a prolonged period of growth after the onset of sexual maturity. However, if we take into account only individuals which did not show such a LAG pattern (i.e. that did not show sudden decrease in bone growth and grew rather evenly), a statistically significant positive correlation between size and age was found for the *P. syriacus* ($Rs = 0.672$, $p < 0.001$), but not for the *P. fuscus* where correlation was negative, though insignificant ($Rs = - 0.191$, $p > 0.05$).

There were significant differences in size among age-classes when tested on pooled data for species. Age-classes were organized in the following way: I (2-7 yr.), II (8-11 yr.) and III (12-16 yr.). In *P. fuscus* intersexual differences in body size in all age-classes were statistically significant (Mann-Whitney U test; I: $p < 0.001$, II: $p < 0.001$; III: $p < 0.01$), females being larger than males. In *P. syriacus* most individuals belonged to age-class II, and intersexual differences in body size were significant ($p < 0.001$), but males had larger body length than females. A posterior analysis among age-classes did not reveal significant differences in size between age-classes (Tukey-Kramer test, $p > 0.05$). Distribution of total body length in respect to age clearly showed, especially when analyzing *P. fuscus* population from Cavolj, that females had greater body length than males from the same age class (Fig. 2). In *P. syriacus* such relation was not present (Fig. 3).

DISCUSSION

Sexual size dimorphism

Among anuran species females appear to be larger than males in 90 % of cases (Shine, 1979). This pattern was found to be true in *P. fuscus*, *P. cultipres* and *P. varaldii* (Halliday & Tejedo, 1995) in many parts of their range. The magnitude of sexual dimorphism (average body size of females *vs.* males) in the common spadefoot toad known so far range from 1.03 (Lesino kopovo, this study) to 1.13 (Poland, Andrzejewski *et al.*, 1977). However, the eastern spadefoot toad males and females show more similar body lengths (1.01, Serbia, this study) or males are significantly larger than females (0.88 in Turkey, Zaloğlu, 1964; 0.93 in FYR Macedonia and Bulgaria, this study). In the case of FYR Macedonia and Bulgaria sample we fail to have young adults in both sexes and the intersexual comparison was done on individuals that probably, in both genders, were close to the maximum size they would reach. Therefore, an interesting result appeared - males were larger than females which is not common in amphibians.

In general, sexual size dimorphism in any species may be a consequence of differences in some life history traits and the action of sexual and/or natural selection, including fecundity selection. Thus, the direction and the degree of SSD may be the result of different selective regimes usually acting separately on females and males. The importance of these regimes varies among species and populations, or even with time in the same population (*e.g.* Howard, 1981; Halliday & Verrell, 1986). Several hypotheses, not mutually exclusive, have been proposed for the evolution of sexual size dimorphism. The most fundamental ones are (1) sexual selection (competition between males and female choice which mostly favors large males), (2) fecundity selection which favors large females, and (3) intersexual niche divergence (for amphibians see reviews in Halliday & Verrell, 1986; Shine, 1989; Halliday & Tejedo, 1995). The evolution of SSD is likely to evolve by interrelationships and correlated trade-offs between life-history adaptations, sexual selection and parameters of fecundity.

In general, as far as proximate determinants of sexual size difference in poikilothermic vertebrates are concerned, of especial importance are difference in age at maturity, longevity, differential growth and mortality rates, in relation to either body-size and age during preadult (larval and juvenile) and adult phases of ontogeny. Among life history characteristics, the timing of maturation is a critical event influencing both morphology and fitness *(i.e.* lifetime reproductive success) of the individuals, as well as the demographic structure of populations and species (Stearns, 1992; Ryan & Semlitsch, 1998). A delay in first reproduction, as large as two years, by females in comparison to males is common in amphibian populations (Halliday & Tejedo, 1995). By delaying maturation, females attain larger body-size at first breeding with a resulting benefit in reproductive performance. The timing of maturation seems to be rather conservative in the genus *Pelobates*, regardless of the region studied, ranging from 2 to 5 years in both genders (Halliday & Tejedo, 1995; this study). Interestingly, in one population of the western spadefoot toad females breed at earlier age than males, which is correlated with a lower level of SSD in comparison with conspecific populations, where females breed later than males, showing higher level of SSD in favor of females (Talavera, 1989). However, in both spadefoot toad species we studied, the time of sexual maturity did not vary significantly between sexes and concomitantly did not affect SSD extent. In comparison to other life history traits with potential effect on the magnitude of SSD studied here, individual age appears not to be sex-specific in any of the spadefoot toad species studied.

Intra- and interspecific differences in life history traits

Size is a dominant ecological factor, particularly among groups with indeterminate growth. Together with age, size is important in determining mortality and fecundity, and in influencing competition within and between species. The importance of body size in the ecology, life history, and reproductive success has been widely acknowledged for years *(e.g.* Fairbairn, 1997). Thus, the pattern of interspecific variation in body size is expected to reflect pattern of adaptive divergence within the species range. That is why one may expect differences in size between individuals of species living in sympatry with other cognate species in comparison to conspecific individuals living in allopatry to decrease and/or escape between-species competition. Contrary to the expectations, spadefoot toads of species living in sympatry appeared not to be consistently larger than conspecific individuals from allopatric parts of the species range. Moreover, sympatric eastern spadefoot toads are significantly smaller than individuals from allopatric populations. However, this finding appears not to be related to sympatry/allopatry at all as deficit of young adult males and females was observed in the allopatric population. Also, males and females reached maturity later and were older in allopatric than in sympatric population, which resulted in larger individuals in the allopatric situation.

As for the interpopulation differences in some life history traits assessed by means of skeletochronology, significant variation was found in both species in the average individual longevity and time of attaining sexual maturity. Of special interest is the fact that *P. syriacus* from the zone of sympatry with *P. fuscus* have shorter life span and breed at least one year earlier in comparison to individuals from allopatric parts of the species range. Thus, our study provides evidence that local environment influences some intraspecific variation in life history traits. However, syntopic spadefoot toad individuals, which share habitat features to a large degree, show number of differences in life-history traits. First, *P. syriacus* adult individuals are significantly larger than *P. fuscus* ones. Most likely this is due to substantial difference in the growth rate of juveniles. Namely, our preliminary results (unpublished) revealed that the juvenile growth rate during the first month was almost twice in *P. syriacus* than in *P. fuscus* living syntopically (Utrine locality). In addition, these two species differ in the magnitude of SSD. They have a different life span and reach sexual maturity at a different age, especially in the females. It might be that our analysis substantiates the possibility that lineage-specific effects can explain some of the pattern of covariation in life history data within the European spadefoot toads.

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VELIKOSTNE RAZLIKE MED SPOLOMA IN ŽIVLJENJSKE ZNAČILNOSTI DVEH EVROPSKIH ČESNOVK *(PELOBATES FUSCUS* IN *P. SYRIACUS)* V ALOPATRIJI IN SIMPATRIJI

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POVZETEK

Avtorji pričujočega znanstvenega dela so preučevali velikostne razlike med spoloma (VRS) in življenjske značilnosti dveh česnovk (Pelobates fuscus *in* P. syriacus) *v delu njunega areala v jugovzhodni Evropi (Panonski nižini in na Balkanu), vključno z območjem njune simpatričnosti. Vrsti se močno razlikujeta po velikosti odraslih osebkov in glede na stopnjo VRS, medtem ko so bile velikostne razlike pri paglavcih in mladostnih osebkih kot tudi v življenjski dobi in času, potrebnem za spolno zrelost, videti precej manjše in brez kakšnega doslednega variacijskega vzorca. Pomembne razlike znotraj vrst so bile odkrite tako pri* P. syriacus *kot* P. fuscus*, in sicer v telesni velikosti, stopnji VRS, povprečni življenjski dobi in času, potrebnem za spolno zrelost. Razlike znotraj vrst v teh značilnostih so bile veliko bolj poudarjene pri vrsti* P. syriacus *kot pri* P. fuscus. *Odrasli osebki vrste* P. syriacus *iz območja striktne simpatrije so bili neprimerno manjši, vendar večji kot paglavci in z manjšo stopnjo VRS. Osebki so imeli tudi krajšo življenjsko dobo in so postajali spolno zreli hitreje (najmanj leto dni) kot istovrstni osebki iz geografsko oddaljenih alopatričnih delov specifičnega areala.*

Ključne besede: rod česnovk, *Pelobates fuscus* in *P. syriacus*, velikost, življenjska doba, spolna zrelost, velikostne razlike med spoloma

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SCIENTIFIC LIFE AND WORK OF NARCIS MRŠIĆ (1951-1997)

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ABSTRACT

The scientific work of Narcis Mršić consists of a number of topics. He made a revolutionary scientific revision of lumbricids. He improved very much the knowledge of zoogeography and taxonomy of lumbricids and diplopods, describing altogether 98 new taxa (12 subspecies, 66 species, 6 subgenera, 11 genera, 2 subfamilies and 1 family), 6 of them in co-authorship. He was firmly convinced that Slovenia should be treated as an important biotic park of Europe. This year we can only spiritually celebrate with him his 50th birthday anniversary.

Key words: Narcis Mršić, scientific work, biodiversity, anniversary

VITA E LAVORO SCIENTIFICO DI NARCIS MRŠIĆ (1951-1997)

SINTESI

Il lavoro scientifico di Narcis Mršić comprende diversi argomenti. Egli portò a termine una rivoluzionaria revisione scientifica dei lumbricidi e arricchì le nostre conoscenze nel campo della zoogeografia e della tassonomia di lumbricidi e diplopodi, descrivendo 98 nuovi taxa (12 sottospecie, 66 specie, 6 sottogeneri, 11 generi, 2 sottofamiglie e 1 famiglia), 6 dei quali con altri autori. Mršić era fermamente convinto che la Slovenia dovrebbe venir considerata come un importante parco biotico dell'Europa. Quest'anno viene spiritualmente celebrato il cinquantesimo anniversario della sua nascita.

Parole chiave: Narcis Mršić, lavoro scientifico, biodiversità, anniversario

INTRODUCTION

He was born in Slovenia, his mother's country. He attended primary and grammar schools in Croatia, his father's land. Then he returned to Slovenia to study biology in Ljubljana. He graduated in 1975, and on March 3rd 1983 he was the first from his generation to defend his doctoral thesis on taxonomic, ecological and coenotic researches in earthworms (Lumbricidae, Oligochaeta) in the transections of Kranjska gora - Mt. Špik and Preddvor - Mt. Storžič.

In 1975 he was engaged, as graduate assistant, by the Jovan Hadži Institute of Biology of the Slovene Academy of Sciences and Arts. Although a zoologist at heart, he began his scientific work in the field of forestry and phytocoenology there. In 1977, he was elected assistant and when getting his PhD, he became a research associate in the Institute's zoological team. In 1994, he was the Institute's deputy director for few months. Since 1992, he was senior research fellow and leader of the Institute's research team in the major research project dealing with floristic, faunistic and vegetation research of Slovenia and adjacent regions.

SCIENTIFIC WORK

Narcis Mršić was extremely prolific in the field of taxonomy as a scientist as well as an organiser in the first years of his scientific career. For his scientific contribution to the knowledge of Slovenia and Western Balkans' faunas he received numerous awards.

He took part in international biological excursions to Nepal (1978), New Guinea (1992), and Indonesia (1993), where he intensely collected material as well as studied the countries' ecology and biodiversity.

In 1995, he was elected assistant professor of ecology at the University of Ljubljana, giving lectures on general and animal ecology, zoogeography and ecosystems to pre- and postgraduate students.

Narcis Mršić was a member of the following international editorial boards: Atlas of European Myriapods, Catalogue of Palearctic Myriapods, Atlas des Reptiles et Amphibiens d'Europe, and reviewer for lumbricids and diplopods for Miscellanea Zoologica, Barcelona (since 1992); for lumbricids for Bios, Thessaloniki (since 1992); for lumbricids and diplopods for Natura Croatica, Zagreb (since 1996); and, since 1993, for The International Foundation Programmes (Soros), Washington. In the years 1989-1991, he was scientific editor in natural sciences for the Enciklopedija Slovenije (Encyclopaedia of Slovenia). In the last few years, he was consultant at the Ministry of Science and Technology and its coordinator of the long-term programme entitled The Natural and Cultural Heritage of the Slovene People, especially in creating an adequate programme for the preservation of biodiversity.

Taxonomically and ecologically, he was dealing with three animal groups: lumbricids, diplopods, and reptiles, while his main ecological preoccupation was dealing with edaphic organisms as a whole and pedogenetic processes. The biodiversity of Slovene territory was a kind of obsession during his last fifteen years. The fact (discovered by him) that this country is an important European biodiversity region inspired him very much indeed.

Narcis Mršić was a very productive scientist. More than 150 scientific, professional, popular, and educational papers and articles written by him constitute a great contribution to the knowledge and advancement of zoology and biology in Slovenia. He was one of our most agile biologists and science was actually his life. In this review, his bibliography is presented according to separate taxa.

LUMBRICIDS

In 38 scientific and professional papers on lumbricids, Narcis Mršić described 46 new species, 3 subgenera, 3 genera, and additionally 3 species, 1 subgenus, and 2 genera as co-author. Individually or as co-author, he also improved 8 descriptions of taxa or changed their status. In his monograph on the earthworms of the Balkans, he analysed, the taxonomic values of setal formulas, muscle bundles types, shape and orientation of nephridial bladders, position of male pore, structure and position of calciferous glands, and typhlosoles. Using these morphological characters, he carried out a complete systematic revision of Lumbricidae.

The lumbricid taxa described by Narcis Mršić

Lumbricidae

Helodrilus dinaricus Mršić, 1991 (sp. n.) (33)
Helodrilus ospensis Mršić, 1991 (sp. n.) (33)
Helodrilus vagneri Mršić, 1991 (sp. n.) (33)
Helodrilus slovenicus Mršić, 1991 (sp. n.) (33)

Cernosvitovia Omodeo, 1956, emend. Mršić & Šapkarev, 1988 (29)
Zicsiona Mršić et Šapkarev, 1987 (subg. n.) (25)
Cernosvitovia (*Zicsiona*) *silicata* Mršić & Šapkarev, 1987 (sp. n.) (25)

Italobalkaniona Mršić & Šapkarev, 1988 (g. n.) (29)
Italobalkaniona treskavicensis Mršić, 1991 (sp. n) (33)

Serbiona Mršić & Šapkarev, 1988 (stat. n.) (29)
Serbiona matjasici Mršić, 1990 (sp. n) (31)
Serbiona carneluttii Mršić, 1990 (sp. n) (31)
Serbiona speciosa Mršić & Šapkarev, 1987 (sp. n.) (25)
Serbiona mayeri Mršić, 1990 (sp. n) (31)

Allolobophora Eisen, 1874, emend. Mršić & Šapkarev, 1988 (29)

Microeophila Omodeo, 1956, emend. Mršić & Šapkarev, 1988 (29)

Panoniona Mršić & Šapkarev, 1988 (stat. n.) (29)

Alpodinaridella Mršić, 1987 (g. n.) (21)
Alpodinaridella Mršić, 1987 (subg. n.) (21)
Alpodinaridella (*Alpodinaridella*) *lozniciana* Mršić, 1987 (sp. n.) (21)
Dinaridella Mršić, 1987 (subg. n.) (21)
Alpodinaridella (*Dinaridella*) *biokovica* (Mršić, 1985) (sp. n.) (16)

Karpatodinariona Mršić & Šapkarev, 1988 (g. n.) (29)

Allolobophoridella Mršić, 1990 (stat. n.) (31)

Apporectodea Örley, 1885, emend. Mršić, 1991 (33)
Apporectodea (*Apporectodea*) *cemernicensis* Mršić, 1991 (sp. n.) (33)
Apporectodea (*Apporectodea*) *papukiana* Mršić, 1987 (sp. n.) (23)
Apporectodea (*Apporectodea*) *pannonilella* Mršić, 1987 (sp. n.) (23)
Apporectodea (*Apporectodea*) *kozjekensis* Mršić, 1991 (sp. n.) (33)
Apporectodea (*Apporectodea*) *bohiniana* Mršić, 1987 (sp. n.) (23)
Creinella Mršić, 1986 (subg. n.) (18)
Apporectodea (*Creinella*) *predalpina* (Mršić, 1986) (sp. n.) (18)

Meroandriella Mršić, 1987 (g. n.) (23)
Meroandriella dinarica Mršić, 1987 (sp. n.) (23)

Octodrilus illyricus Mršić, 1987 (sp. n.) (24)
Octodrilus kvarnerus Mršić, 1987 (sp. n.) (24)
Octodrilus oesopgagus Mršić, 1991 (sp. n.) (33)
Octodrilus velebiticus Mršić, 1991 (sp. n.) (33)
Octodrilus istrianus Mršić, 1991 (sp. n.) (33)
Octodrilus savinensis Mršić, 1987 (sp. n.) (24)
Octodrilus meroandricus Mršić, 1985 (sp. n.) (23)
Octodrilus preudolissaensis Mršić, 1991 (sp. n.) (33)
Octodrilus zirianus Mršić, 1987 (sp. n.) (24)
Octodrilus pseudozirianus Mršić, 1987 (sp. n.) (33)

Octodriloides poklonensis Mršić, 1991 (sp. n.) (33)
Octodriloides marinceki Mršić, 1987 (sp. n.) (22)
Octodriloides dinaricus Mršić, 1991 (sp. n.) (33)
Octodriloides zupancici Mršić, 1991 (sp. n.) (22)
Octodriloides bolei Mršić, 1987 (sp. n.) (22)
Octodriloides nazarensis Mršić, 1991 (sp. n.) (33)
Octodriloides bosniensis Mršić, 1991 (sp. n.) (33)

Fitzingeria Zicsi, 1978, emend. Mršić, 1991 (33)
Fitzingeria viminiana Mršić, 1986 (sp. n.) (17)

Dendrobaena velkovrhi Mršić, 1988 (sp. n.) (26)
Dendrobaena papukiana Mršić, 1988 (sp. n.) (26)
Dendrobaena durmitorensis Mršić, 1988 (sp. n.) (26)
Dendrobaena jastrebensis Mršić & Šapkarev, 1987 (sp. n.) (25)
Dendrobaena jahorensis Mršić, 1991 (sp. n.) (33)
Dendrobaena bosniaca Mršić, 1988 (sp. n.) (26)
Dendrobaena macedonica Mršić, 1991 (sp. n.) (33)
Dendrobaena vranicensis Mršić, 1991 (sp. n.) (33)
Dendrobaena grmecensis Mršić, 1991 (sp. n.) (33)
Dendrobaena montenegrina Mršić, 1988 (sp. n.) (26)
Dendrobaena hamzalensis Mršić, 1991 (sp. n.) (33)
Dendrobaena slovenica Mršić, 1991 (sp. n.) (33)

1. **Kerovec, M. & N. Mršić (1981):** Oligochaeta. Catalogus faunae Jugoslaviae III/1, Slovenska akademija znanosti in umetnosti, Ljubljana, 1-38.
2. **Mršić, N. (1977):** Prispevek k poznavanju vrste *Eisenia lucens* (Waga 1857) (Lumbricidae, Oligochaeta) v Sloveniji. Biol. vestn., 25(2), 139-147.
3. **Mršić, N. (1979):** Naselitvene sukcesije deževnikov (Lumbricidae, Oligochaeta) v bukov les na Kočevskem. Biol. vestn., 27(2), 157-164.
4. **Mršić, N. (1980):** *Octolasium croaticum* (Rosa 1895) nova vrsta deževnika (Lumbricidae) v Sloveniji. Biol. vestn., 28(1), 59-65.
5. **Mršić, N. (1980):** A review of the Oligochaeta and some new species of earthworm (Lumbricidae) v Sloveniji. Biol. vestn., 28(2), 27-38.
6. **Mršić, N. (1982):** *Allolobophora altimontana* sp. n. (Oligochaeta, Lumbricidae) a new species in Slovenia. Biol. vestn., 30(2), 57-62.
7. **Mršić, N. (1982):** Classification of some earthworm associations in Slovenia, worked out on the basis of the new coefficient of percentile similitarity. Biol. vestn., 30(2), 63-84.
8. **Mršić, N. (1982):** Taksonomske, zoogeografske in cenotske raziskave deževnikov (Lumbricidae, Oligochaeta) gorskega sveta Slovenije. Razpr. - Slov. akad. znan. umet., Razr. naravosl. vede, 24(4), 159-256.
9. **Mršić, N. (1983):** Research on fauna and associations of earthworms (Lumbricidae) in Durmitor, Crna Gora (Montenegro). Biol. vestn., 31(2), 53-66.
10. **Mršić, N. (1983):** Seasonal dynamics of abundance, age structure and depth distribution of earthworms (Lumbricidae) in some associations in Slovenia. Biol. vestn., 31(2), 67-82.
11. **Mršić, N. (1983):** Effect of edaphic factors on distribution of earthworms (Lumbricidae) in certain associations in Slovenia. Acta biologica Iugoslavica, Ekologija, 18(1), 43-54.
12. **Mršić, N. (1984):** Research on the fauna and associations of earthworms (Lumbricidae) in Velebit and

Kapela, Hrvatska (Croatia). Biol. vestn., 32(1), 55-69.

13. **Mršić, N. (1984):** Cenotske raziskave deževnikov (Lumbricidae, Oligochaeta) gorskega sveta zahodne Jugoslavije. Razpr. - Slov. akad. znan. umet., Razr. naravosl. vede, 25(6), 309-358.
14. **Mršić, N. (1985):** Research on the fauna and associations of earthworms (Lumbricidae) in the region of Učka and Gorski Kotar. Biol. vestn., 33(1), 41-55.
15. **Mršić, N. (1985):** Nekatere nove vrste za favno in cenotske raziskave deževnikov (Lumbricidae, Oligochaeta) Slovenije. Scopolia, 8, 1-32.
16. **Mršić, N. (1985):** *Allolobophora biokovica* sp. n. (Oligochaeta, Lumbricidae) and earthworm associations of the Biokovo (Croatia). Biol. vestn., 34(1), 69-80.
17. **Mršić, N. (1986):** *Fitzingeria viminiana* sp. N. (Lumbricidae) and the earthworm fauna (Lumbricidae) of northeastern Serbia. Acta biologica Iugoslavica, Biosistematika, 12(2), 111-117.
18. **Mršić, N. (1986):** *Creinella predalpina* g. n., sp. N. (Oligochaeta: Lumbricidae). Glas. Prir. muz. Beogr., B 41, 37-40.
19. **Mršić, N. (1986):** Deževniki: biologija in gojenje. (Lumbricids: their biology and breeding.) ČZP Kmečki glas, Ljubljana, str. 69.
20. **Mršić, N. (1987):** *Allolobophora oculata* (Hoffmeister 1845) new earthworm species (Lumbricidae) in the fauna of Yugoslavia. Biol. vestn.. 35(1), 67-75.
21. **Mršić, N. (1987):** *Alpodinaridella* g. n. (Oligochaeta: Lumbricidae) and description of New Monotypic Subgenera. Biol. vestn., 35(2), 61-66.
22. **Mršić, N. (1987):** Description of three new species of earthworm of the genus *Octodriloides* Zicsi 1986 (Oligochaeta: Lumbricidae). Biol. vestn., 35(2), 87-93.
23. **Mršić, N. (1987):** Description of a New Genus and Five New Species of Earthworms (Oligochaeta: Lumbricidae). Scopolia, 13, 1-11.
24. **Mršić, N. (1987):** Description of the five new species of the genus *Octodrilus* Omodeo 1956 (Oligochaeta: Lumbricidae). Acta biologica Iugoslavica, Biosistematika, 13(1), 37-44.
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26. **Mršić, N. (1987):** Present State of Research in the Earthworm Fauna (Lumbricidae) of Yugoslavia. In: Bonvici-Pagliai, A. M. & P. Omodeo (eds.): On Earthworms. Selected Symposia and Monographs U.Z.I. 2, Mucchi, Modena, 329-344.
27. **Mršić, N. (1988):** Description of Five new Species of Earthworms of the Genus *Dendrobaena* Eisen 1874 (Lumbricidae). Biol. vestn., 36(1), 13-24.
28. **Mršić, N. (1988):** *Allolobophora parva* (Eisen 1874) - new species in the fauna of Slovenia - and degree to which earthworms (Lumbricidae) have been investigated in Yugoslavia. Biol. vestn., 36(1), 25-31.
29. **Mršić, N. & J. Šapkarev (1988):** Revision of the genus *Allolobophora* Eisen 1874 (sensu Pop 1941) (Lumbricidae, Oligochaeta). Acta Mus. maced. sci. nat., 19(1/154), 1-38.
30. **Mršić, N. (1989):** Research on the fauna and associations of earthworms (Lumbricidae) in northeastern Serbia, II. Biol. vestn., 37(2), 37-60.
31. **Mršić, N. (1990):** Description of a New Subgenus, Three New Species, and Taxonomic Problems of the Genus *Allolobophora* sensu Mršić and Šapkarev 1988 (Lumbricidae, Oligochaeta). Biol. vestn., 38(1), 49-68.
32. **Mršić, N. (1990):** Research of the fauna and associations of earthworms (Lumbricidae) in Durmitor, Montenegro II. Glas. Od. prir. nauka - Crnog. akad. nauka umjet., 23(3), 71-90.
33. **Mršić, N. (1991):** Monograph on earthworms (Lumbricidae) of the Balkans I. Monografija o deževnikih (Lumbricidae) Balkana I. Dela 31, Slovenska akademija znanosti in umetnosti, Ljubljana, 355 str.
34. **Mršić, N. (1991):** Monograph on earthworms (Lumbricidae) of the Balkans II. Monografija o deževnikih (Lumbricidae) Balkana I. Dela 31, Slovenska akademija znanosti in umetnosti, Ljubljana, str. 356-757.
35. **Mršić, N. (1992):** Rdeči seznam ogroženih deževnikov (Lumbricidae, Oligochaeta) v Sloveniji. (The red list of the endengered lumbricids in Slovenia.) Varst. narave, 17, 179-181.
36. **Mršić, N. (1992):** Revision of the genera *Cernosvitovia* Omodeo, 1956, *Italobalkaniona* Mršić & Šapkarev, 1988 and *Allolobophora* Eisen, 1874 from the Balkans. Miscellanea Zool., 16, 21-28.
37. **Mršić, N. (1992):** Deževniki (Lumbricidae) Dolenjske. (Lumbricids (Lumbricidae) of the Dolenjska.) In: Hudoklin, A. (ed.): Dolenjski zbornik 1992, Novo Mesto, str. 122-125.
38. **Mršić, N. (1996):** Deževniki (Lumbricidae): pomen, stanje raziskanosti in ogroženost. (Lumbricids (Lumbricidae): their Significance, State of Research and Threat Status.) In: Gregori, J., A. Martinčič, K. Tarman, O. Urbanc-Berčič, D. Tome & M. Zupančič (eds.): Narava Slovenije, stanje in perspektive. Zbornik prispevkov o naravni dediščini Slovenije, Društvo ekologov Slovenije, Ljubljana, str. 213-218.

DIPLOPODS

In 26 scientific and professional papers on diplopods, Mršić dealt with faunistics and taxonomy. In his treatise on Attemsiidae, he analysed male and female genitalia and made a determination key for both sexes. Besides, he substantiated the status of some taxa. He described 12 new subspecies, 17 species, 2 subgenera, 6 genera, 2 subfamilies, and 1 family (the works in print are not included).

The diplopod taxa, described by Narcis Mršić

Polydesmidae

Polydesmus (Acanthotarsius) pseudoedentulus Mršić, 1986 (sp. n.) (4)
Polydesmus (Basicentrus) fontius saviniense Mršić, 1986 (ssp. n.) (4)
Absurdodesmus Mršić, 1988 (subg. n.) (11)
Polydesmus (Absurdodesmus) jalzici Mršić, 1988 (sp. n.) (11)
Polydesmus (Absurdodesmus) novaki Mršić, 1988 (sp. n.) (11)
Polydesmus (Nomarchus) juergengruberi Mršić, 1994 (sp. n.) (22)
Brachydesmus (Brachydesmus) liboensis Mršić, 1988 (sp. n.) (13)
Brachydesmus (Brachydesmus) macedonicus Mršić, 1988 (sp. n.) (13)
Brachydesmus (Brachydesmus) splitensis ragusensis Mršić, 1988 (ssp. n.) (13)
Brachydesmus (Brachydesmus) herzegowinensis serbicus Mršić, 1988 (ssp. n.) (13)
Brachydesmus (Brachydesmus) inferus velebiticus Mršić, 1988 (ssp. n.) (13)
(*Brachydesmus (Brachydesmus) calcarius* Kovačević, 1928) (redescription) (13)
Brachydesmus (Brachydesmus) henrikenghoffi Mršić, 1994 (sp. n.) (22)

Haaseidae

Haasea (Brachybainosoma) lacusnigri intermedia Mršić, 1985 (ssp. n.) (2)

Craspedosomatidae

Desultorosoma Mršić, 1985 (subg. n.) (1)
Dyocerasoma (Desultorosoma) drimicum Mršić, 1985 (sp. n.) (1)
Dyocerasoma (Dyocerasoma) biokovense Mršić, 1986 (sp. n.) (3)
Ochogona (Ochogona) pusillum amabilitatum Mršić, 1986 (ssp. n.) (4)
Ochogona (Ochogona) pusillum celjense Mršić, 1986 (ssp. n.) (10)
Ochogona (Ochogona) pusillum zagrebense Mršić, 1986 (ssp. n.) (10)
Craspedosoma montenegrina Mršić, 1987 (sp. n.) (5)

Neotractosomatidae

Schizmohetera Mršić, 1987 (g. n.) (6)
Schizmohetera sketi Mršić, 1987 (sp. n.) (6)

Julidae

Orioiulus Mršić, 1987 (subg. n.) (8)
Xestoiulus (Orioiulus) dalmaticus Mršić, 1987 (sp. n.) (8)
Interleptoiulus Mršić, 1988 (g. n.) (12)
Interleptoiulus cernagorans Mršić, 1988 (sp. n.) (12)

Biokoviellidae Mršić, 1992 (fam. nov.) (15)

Biokoviella Mršić, 1992 (g. n.) (15)
Biokoviella mauriesi Mršić, 1992 (sp. n.) (15)

Anthogonidae

Macrochaetosomatinae Mršić, 1992 (subfam. n.) (15)
Macrochaetosoma troglomontanum biokovense Mršić, 1987 (ssp. n.) (9)

Attemsiidae

Grassografinae Mršić, 1987 (subfam. n.) (7)
Grassografia Mršić, 1987 (g. n.) (7)
Grassografia makolensis Mršić, 1987 (sp. n.) (7)
Mecogonopodium zirianus Mršić, 1987 (sp. n.) (7)
Glomogonium karawankarum saviniense Mršić, 1987 (ssp. n.) (7)
Glomogonium karawankarum intermedium Mršić, 1987 (ssp. n.) (7)
Stiphrogonium attemsi celeae Mršić, 1987 (ssp. n.) (7)

Paradoxosomatidae

Malayorthomorpha Mršić, 1996 (g. n.) (22)
Malayorthomorpha siveci Mršić, 1996 (sp. n.) (22)
Haplogonomorpha Mršić, 1996 (g. n.) (22)
Haplogonomorpha gogalai Mršić, 1996 (sp. n.) (22)
Anoplodesmus tarmani Mršić, 1996 (sp. n.) (22)

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3. **Mršić, N. (1986):** *Dyocerasoma (Dyocerasoma) biokovense* sp. n. (Diplopoda: Craspedosomatidae). Biol. vestn., 34(1), 81-87.
4. **Mršić, N. (1986):** New taxa of the Diplopods (Myriapoda, Diplopod) of Slovenia. Biol. vestn., 34(2), 65-77.
5. **Mršić, N. (1987):** *Craspedosoma montenegrina* sp. n. (Diplopoda: Craspedosomatidae). Biol. vestn., 35(1), 59-65.
6. **Mršić, N. (1987):** *Schizmohetera sketi* g. n., sp. n. (Diplopoda: Neotractosomatidae). Biol. vestn., 35(1), 77-82.

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8. **Mršić, N. (1987):** Genus *Xestoiulus* Verhoeff 1893 (Diplopoda: Julidae) in Yugoslavia. Razpr. - Slov. akad. znan. umet., Razr. naravosl. vede, 28(1), 3-25.
9. **Mršić, N. (1987):** Diplopod fauna (Diplopoda: Myriapoda) Biokova. Acta biokov., 4, 267-276.
10. **Mršić, N. (1987):** Genus *Ochogona* Cook 1895 (Craspedosomatidae, Diplopoda) of Yugoslavia. Glas. Prir. muz. Beogr., B 42, 51-74.
11. **Mršić, N. (1988):** Description of a New Subgenus and Two New Species of the Genus *Polydesmus* Latreille 1802 (Diplopoda). Biol. vestn., 36(2), 25-30.
12. **Mršić, N. (1988):** *Interleptoiulus cernagorans* g. n., sp. n. (Diplopoda: Julidae) and a Survey of the Tribus *Leptoiulini* in Yugoslavia. Biol. vestn., 36(2), 31-51.
13. **Mršić, N. (1988):** Polydesmida (Diplopoda) of Yugoslavia. I. Razpr. - Slov. akad. znan. umet., Razpr. naravosl. vede, 29(3), 69-112.
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19. **Mršić, N. (1994):** Dvojnonoge (Diplopoda) Koprskega primorja in sosednjih območij. (The Diplopods of the Koprsko primorje and the adjacent regions.) Annales, 4, 15-30.
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21. **Mršić, N. (1994):** *Polydesmus (Nomarchus) juergengruberi* sp. n., *Brachydesmus (Brachydesmus) henrikenghoffi* sp. n. (Diplopoda) of Macedonia. Zool. Anz., 5/6, 177-180.
22. **Mršić, N. (1996):** On three new Paradoxosomatidae from Malaysia (Diplopoda Polydesmida). Arthr. Selecta, 5(1/2), 139-144.
23. **Mršić, N. (1996):** Dvojnonoge (Diplopoda) - pomen, stanje raziskanosti in ogroženosti. (Diplopoda - their Significance, State of Research and Threat Status.) In: Gregori, J., A. Martinčič, K. Tarman, O. Urbanc-Berčič, D. Tome & M. Zupančič (eds.): Narava Slovenije, stanje in perspektive. Zbornik prispevkov o naravni dediščini Slovenije, Društvo ekologov Slovenije, Ljubljana, str. 263-267.
24. **Mršić, N., T. Novak, F. Potočnik & T. Amon (1996):** Ecological evaluation of oniscoids and diplopods from cavities in Slovenia. Mem. Biospeol., 23, 203-210.

in print

1. **Mršić, N.** New Paradoxosomatid taxons (Diplopoda: Paradoxosomatidae) from Irian Jaya (western New Guinea). Tijd. Entom.
2. **Mršić, N.** New Diplopod Taxons (Diplopoda: Paradoxosomatidae) from Indonesia. Contr. Zool.

REPTILES

As far as reptiles are concerned, Mršić was especially interested in the speciation of the lizards genera *Lacerta* and *Podarcis* of the coastal parts of Croatia (Hrvatsko Primorje, Dalmatia) and the Adriatic isles.

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EDAPHIC ANIMALS

For his book on edaphic animals, he made about 1200 excellent drawings of animals, thus preparing one of the most exhaustive recent representations of the edaphon in Slovenia and in the world in general.

1. **Mršić, N. & T. Novak (1995):** Vzorčenje in določanje talnih živali. (Sampling and determination of soil fauna.) Zavod RS za šolstvo, Ljubljana, 109 str.
2. **Mršić, N. (1997):** Živali naših tal. Uvod v pedozoologijo - sistematika in ekologija s splošnim pregledom talnih živali. (Animals of our soils. The introduction to pedozoology - systematics and ecology with an review upon the soil animals.) Tehniška založba Slovenije, Ljubljana, 416 str.

BIODIVERSITY

In his works on the biodiversity of Slovene territory, he proved that its south-western parts, and the adjacent regions in Italy and Croatia, constitute a biotically very rich European region for the following reasons: biogeographical (junction of the Alpine, Central European, Sub-Pannonian, Sub-Mediterranean and Dinaric regions), geohistorical (the Adriatic tectonic plate, initially a part of Gondwana, paleoclimatic changes, *etc.),* geological (very diverse geological structure, extensive limestone), and consequent *(e.g.* pedological) ones. Among them, the past tectonic events were found out to exert significant influence upon the diversification processes and speciation of some groups, *e.g.* attemsiid diplopods. He gave his heart to the idea that the region should be treated as an important biotic park of Europe.

1. **Sket, B., J. Bole, A. Benović, A. Brancelj, J. Brglez, M. Čuček, B. Ćurčić, A. Jaklin, G. Karaman, I. Katavić, M. Kerovec, I. Kos, M. Legac, N. Mršić, A. Mulej, T. Novak, S. Petkovski, T. Petkovski, A. Polenec, F. Potočnik, V. Pujin, B. Radujković, Z. Števčić, K. Tarman, A. Travizi, M. Velikonja, F. Velkovrh, J. Vidsković, & D. Zavodnik (1991):** Bogastvo in raziskanost jugoslovanske favne: nižji nevretenčarji (Metazoa Invertebrata, ex. Insecta). Biol. vestn., 39(1/2), 37-51.
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MISCELLANEA

1. **Novak, T., N. Mršić & F. Potočnik (1996):** Biomass and its energetic evaluation of cavities at Slovenia. Mem. Biospeol., 23, 65-71.

CONCLUSIONS

Beside the above listed works, Narcis Mršić wrote 17 unpublished expertises on lumbricids, diplopods, reptiles and biodiversity, 16 published summaries from scientific conferences, he prepared 4 contributions to the Encyclopaedia of Slovenia, 9 educational contributions, published 24 popular articles, and translated a small book from Slovene to Croatian. He was a mentor in 4 diploma works, one master- and one doctor thesis. Beside his works, he illustrated two more books. Being a perfectionist in drawing, this was not the case as far as some of his last written works are concerned (*cf.* Tarman, 1997). Was this due to his premonition of leaving us soon?

The scientific work of Narcis Mršić consists of a number of topics. He made a revolutionary scientific revision of lumbricids. He improved very much the knowledge of zoogeography and taxonomy of lumbricids and diplopods, describing altogether 98 new taxa (12 subspecies, 66 species, 6 subgenera, 11 genera, 2 subfamilies and 1 family), 6 of them in co-authorship. His excellently illustrated handbook on soil fauna is a comprehensive pedozoological presentation of soil animals, revealing our scarce knowledge of many species and need for further investigations. His zeal to present Slovenia as an important European biodiversity region triggered off a national awareness upon this question and a great scientific interest of colleagues in a profound research in this respect. Indeed, many things to remember Narcis Mršić. He left us much too soon. This year we can only spiritually celebrate with him his 50th birthday anniversary. The chronological review of the bibliography of Narcis Mršić is presented on the internet: http://www.izum.si under the COBISS basis.

ZNANSTVENO ŽIVLJENJE IN DELO NARCISA MRŠIĆA (1951-1997)

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POVZETEK

Znanstveno delo Narcisa Mršića sestoji iz različnih tem. Opravil je revolucionarno revizijo lumbricidov. V veliki meri je obogatil naše znanje, kar zadeva zoogeografijo in taksonomijo lumbricidov in diplopodov, saj je opisal kar 98 novih taksonov (12 podvrst, 66 vrst, 6 podrodov, 11 rodov, 2 poddružin, in 1 družine), 6 od teh v soavtorstvu. Njegov izvrstno ilustrirani priročnik o talni favni je vsestranska pedozoološka predstavitev talnih živali, ki pravzaprav razkriva naše skromno znanje o mnogih talnih vrstah in potrebi po novih raziskavah. Njegova velika vnema, da Slovenijo predstavi kot pomembno evropsko biodiverzitetno regijo, je sprožila nekakšno narodno ozaveščenost in veliko znanstveno zanimanje kolegov za temeljite raziskave na tem področju. Zares mnogo razlogov za spomin na Narcisa Mršića, ki nas je zapustil veliko prezgodaj. Letos lahko z njim le v duhu praznujemo njegovo petdesetletnico.

Ključne besede: Narcis Mršić, znanstveno delo, biodiverziteta, obletnica

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DELO NAŠIH DRUŠTEV / OCENE

ATTIVITÀ DEI NOSTRI ISTITUTI E DELLE NOSTRE SOCIETÀ / RECENSIONI

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ATTIVITÀ DEI NOSTRI ISTITUTI E DELLE NOSTRE SOCIETÀ
ACTIVITIES BY OUR INSTITUTIONS AND ASSOCIATIONS

ŽIVO SREBRO V OBMOČJU IDRIJE IN SEVERNEGA JADRANA

Workshop on

Mercury in the Idrija Region and the Northern Adriatic

Rudnik živega srebra v Idriji, drugi največji rudnik te rude na svetu, je nepretrgoma deloval skoraj 500 let. V tem času so odkopali prek 5 milijonov ton živosrebrove rude, večinoma v obliki cinabarita, in več kot 25% pridobljenega živega srebra se je porazgubilo v okolju. Emisije v metalurškem procesu in prezračevanje rudniških jaškov je povzročalo visoke koncentracije živega srebra v zraku, ki se je večinoma deponiralo v območju Idrije. Glavni vzrok za povišano koncentracijo živega srebra v okoliški prsti je odlaganje ostankov žganja in jalovine. Remobilizacija materiala je prispevala k akumulaciji živega srebra v rečnih naplavinah, prsti in rečnih sedimentih. Danes še vedno poteka vnos živega srebra z reko Sočo v Tržaški zaliv, kjer se kopiči v užitnih morskih organizmih, tudi gojenih v marikulturi, in tako lahko pomeni zdravstveni, ekonomski in socialni problem za lokalno prebivalstvo.

Vrsta raziskav, opravljenih v zadnjih letih, je zajela različne vidike živega srebra v območju Idrije in severnega Jadrana, ki vključujejo porazdelitev, speciacijo, akumulacijo, vpliv in kroženje živega srebra. V organizaciji Instituta Jožef Stefan, Morske biološke postaje Nacionalnega inštituta za biologijo in Univerze na Alaski je 14. in 15. maja 2001 v Portorožu potekala mednarodna delavnica pod naslovom **"Živo srebro v območju Idrije in severnega Jadrana"**. Delavnico smo organizirali v okviru slovensko-ameriškega znanstvenega projekta "Biogeokemija živega srebra v porečju Idrijce: procesi metilacije in demetilacije". Organizacijo delavnice so podprli Ministrstvo za šolstvo, znanost in šport, Ministrstvo za okolje in prostor, Nacionalna znantvena fundacija ZDA (NSF), Fakulteta za pomorstvo in promet Univerze v Ljubljani, Slovenska znanstvena fundacija in Rudnik živega srebra Idrija. Namen delavnice je bil zbrati raziskovalce, ki se ukvarjajo s kroženjem in vplivom živega srebra v rekah in morju, prsti, atmosferi in organizmih ter vplivom na zdravje ljudi. Poseben poudarek smo posvetili primerjavam z drugimi okolji, obremenjenimi z živim srebrom. V delavnici so sodelovali raziskovalci iz Slovenije, Italije, Hrvaške, Nemčije, Francije, Španije, Rusije, Češke in ZDA. Daljši povzetki prispevkov (referatov in posterjev) so zbrani v 1. številki letnika 48 revije RMZ - Materials and Geoenvironment.

Splošno

W. B. Lyons z Univerze Ohio v Columbusu (ZDA) je podal pregled današnjega znanja o izvorih in pretvorbah živega srebra v okolju, ki je globalni polutant, strupen v nizkih koncentracijah zaradi svoje sposobnosti kopičenja v prehranjevalni verigi. Najpomembnejši izvor antropogenega živega srebra je atmosfera, med najpomembnejšimi točkastimi izvori pa je današnja in pretekla rudarska dejavnost, kamor sodi tudi Idrija. Večina antropogenega živega srebra izvira iz izgorevanja fosilnih goriv, predvsem premoga. Le malo živega srebra, deponiranega na kopnem, se izpira v reke, tisti del, ki preide v reke, pa je izpostavljen metilaciji in demetilaciji. Pomembna mesta metilacije in demetilacije so mokrišča. Porazdelitev živega srebra v rekah je povezana s koncentracijo suspendirane snovi in raztopljene organske snovi. Sedimenti so končni depo živega srebra in živo srebro v jedrih sedimentov je kazalec razmer v preteklosti. **J. E. Gray** z Geološkega zavoda ZDA v Denverju je prikazal pregled transporta in kroženja živega srebra ter vplivov rudnikov živega srebra na okolje na primerih nahajališč v pacifiškem območju. V teh rudiščih, kjer je ruda pretežno cinabarit, koncentracija pirita nizka in rudniške vode nevtralne, je zaradi male topnosti živega srebra koncentracija metil živega srebra nizka. V nahajališčih s silikatnimi in karbonatnimi minerali pa so koncentracije metil živega srebra višje. Bližina mokrišč z visoko vsebnostjo organske snovi, spremenljivimi klimatskimi razmerami in rudniške vode z visokimi koncentracijami raztopljenega živega srebra pospešujejo metilacijo. Izliv takih vod v obalno morje vodi do metilacije živega srebra v morskem okolju, do kopičenja v užitnih morskih organizmih in prehoda v ljudi. **F. Baldi** z Univerze Ca Foscari v Benetkah (Italija) je prikazal rezultate raziskav vpliva sulfatoredukcijskih bakterij na razgradnjo metil živega srebra in nastanek elementnega (Hg(0)) v aerobnem in dimetil živega srebra v anaerobnem okolju. **K. Duddlestone** z Univerze na Alaski v Anchorageu (ZDA) in sodelavaci so na osnovi poskusov v morskih in sladkovodnih sedimentih in prsti z različnih lokacij v severni Ameriki in Evropi pokazali, da poteka metilacija živega srebra pretežno anaerobno, aerobne razmere pa pospešujejo reduktivno demetilacijo. Procese, ki vplivajo na porazdelitev živega srebra v atmosferi, so prikazali **R. Ferrara** in sodelavci z Inštituta CNR za biofiziko iz Pise (Italija), **N. Pirrone** in **I. Hedgecock** z Inštituta CNR za študij onesnaževanja zraka iz Rende (Italija) in **R. Ebinghaus** iz GKSS Geesthacht (ZR Nemčija). Od treh najpomembnejših nahajališč v sredozemskem bazenu, Almadena (Španija), Mt. Amiate (Italija) in Idrije, ki so prispevala približno 50% celotne svetovne proizvodnje živega srebra, obratuje danes le Almaden. Druga so degradirana okolja, opuščene naprave in kupi ostankov prežganega cinabarita, ki vsebuje ostanke elementnega živega srebra. Nizki izkoristki v postopkih pridobivanja v preteklosti so prispevali k razširjanju kovine v plinastem stanju in delcih po atmosferi, zemlji in vodi. Biološki monitoring in analize v zraku in padavinah kažejo visoke koncentracije živega srebra. Uporaba novih analiznih tehnik (laserske spektroskopije) omogoča prostorsko in časovno detekcijo ter določanje tokov živega srebra v atmosferi. Tako so določili glavne izvore živega srebra v zraku v Almadenu in Mt. Amiati: metalurški postopek, prezračevanje rudniških jaškov, prežgani odpadni cinabarit in kontaminirana prst v bližini naprav. Koncentracije živega srebra v zraku kažejo na visoke koncentracije nad Almadenom v poletnem in jesenskem obdobju zaradi lokalnega reliefa in prevladujoče smeri vetrov. V Mt. Amiati sta območji povišanih koncentracij živega srebra v zraku v bližini opuščenega rudnika in v bližini termoenergetskega objekta. Porazdelitev živega srebra v zraku v Idriji je visoka v bližini opuščene peči in rudniške prezračevalne naprave. V Mt. Amiati je viden padec koncentracije nad opuščenim rudnikom v zimskem obdobju nizkih temperatur. Študij porazdelitve, transporta in kroženja živega srebra v atmosferi nad Sredozemljem poteka danes z ustreznimi modeli, ki so uporabni v načrtovanju strategij za zmanjšanje emisij živega srebra v območju. V polarnih območjih, ki so danes pod močnim vplivom naravnih in antropogenih emisij živega srebra, so nižje koncentracije vidne v času polarnih noči in so posledica oksidacije, adsorpcije in depozicije plinastega živega srebra.

Območje Idrije

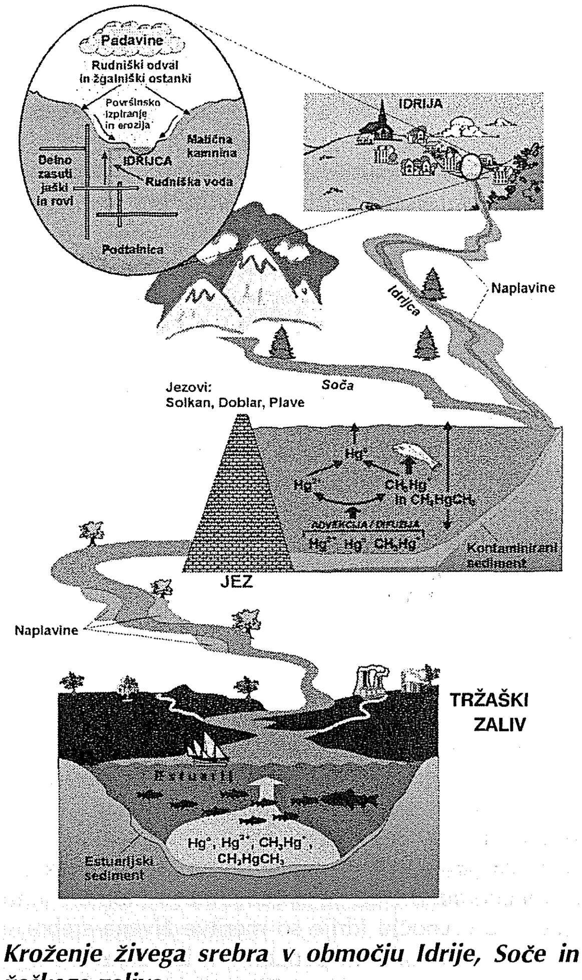
S. Pirc z Univerze v Ljubljani je prikazal splošne geološke in geokemijske značilnosti živega srebra na območju Slovenije s pregledom vsebnosti živega srebra v litosferi, pedosferi, hidrosferi, biosferi in antroposferi. Močni tektonski premiki v srednjem Triasu so omogočili akumulacijo živosrebrove rude v idrijskem bazenu. Razširjena je v smer NW-SE v dolžini 1,5 km, širini 0,3-0,6 km in do globine 120 m. Prevladuje cinabarit, zaznati pa je tudi samorodno živo srebro in v manjših količinah še metacinabarit. Drugi minerali so še pirit, markazit, dolomit, kalcit, kaolinit, epsomit in melanterit. V prsti so opazne do dvakrat povišane koncentracije živega srebra v zahodni Sloveniji glede na vzhodni del. Povišane koncentracije živega srebra v prsti so opazili tudi v dolini Soče kot posledica uporabe živosrebrovega fulminata med prvo svetovno vojno. V prsti urbaniziranih področij zbuja pozornost območje Kopra z najvišjimi koncentracijami. Opisana porazdelitev je vidna tudi v rečnih sedimentih in podtalnici. V atmosferi Idrije so med delovanjem rudnika (1970) ugotovili izredno visoke koncentracije, ki pa so se v 90. letih znižale. Porazdelitev koncentracij nad Idrijo danes močno varira in je odvisna predvsem od jakosti in smeri vetrov. Raziskave živega srebra v prahu naselij in hiš so pokazale, da so najvišje koncentracije v prahu v Kopru, na Jesenicah in v Celju. **R. Rajar** z Univerze v Ljubljani je podal pregled hidrologije Idrijce in Soče ter Tržaškega z zaliva, ki je pomembna za razumevanje transporta in porazdelitve živega srebra v porečju in zalivu. Količina padavin v porečju Idrijce in Soče je visoka in močno varira. Zaradi konfiguracije terena je erozija precejšnja, vendra je transport delcev omejen zaradi treh jezov na Soči (Doblar, Plave, Solkan). Hidrologija Soče je dobro znana na slovenski strani (Solkan) s povprečnim pretokom približno 100 m^3/s z dvema izrazitima sezonskima vrhovoma: daljši na pomlad zaradi taljenja snega v Alpah in krajši, a močnejši zaradi padavin jeseni. Pomemben pritok po Solkanu je Vipava. Na italijanski strani ni obsežnejših kontinuiranih meritev pretoka Soče, čemur se pridružuje še zapletena hidrologija porečja, ki vključuje pritok Ter in reko Timavo, ki se neposredno izliva v Tržaški zaliv. Ocenjeni povprečni pretok reke Soče na izlivu je 170 m^3/s. Na povprečno tokovanje v Tržaškem zalivu vplivajo vetrovi (predvsem burja in jugo), sladkovodni pritoki (vplivajo predvsem ob ustju, razen ob visokem rečnem pretoku), plimovanje in termohaline razmere. Smer toka v zalivu je pretežno ciklonalna, kar vpliva na porazdelitev vnešenga živega srebra v zaliv, ki se razširja predvsem ob severni obali v zahodni smeri. **T. Dizdarevič** z Rudnika živega srebra v Idriji je prikazala vpliv idrijskega rudnika na okolje od začetkov leta 1490, mimo odkritja bogate žile cinabarita leta 1508, do dokončnega zaprtja leta 1994. Nahajališče leži pod mestom. Približno 70% rude je cinabarita, 30% pa samorodnega živega srebra. V preteklosti je bila vsebnost živega srebra v rudi bistveno večja. Največja produkcija živega srebra je bila dosežena leta 1913, in sicer 820 ton. Izkoristek pridobivanja je bil v preteklosti nizek, do 75% do leta 1948 in približno 90% po letu 1961. Prežgani cinabarit so odlagali v bližini naprav. V 500 letih so odkopali prek 12 miljonov ton rude, pridobili 153.000 ton živega srebra, od katerega je 44.500 ton kontaminiralo okolje med Idrijo in Tržaškim zalivom. Emisije v atmosfero so dosegale približno 7-10 ton letno. Koncentracije v zraku so bile v času delovanja v sedemdesetih letih zelo visoke, znižale so se v času zmanjšanega obratovanja, danes pa so povišane le ob rudniških zračnikih in kupih jalovine. V prsti v območju Idrije je koncentracija živega srebra zelo visoka. Rudniške vode, bogate z živim srebrom, so se izlivale v Idrijco, povišane koncentracije železa in sulfata kot posledica žganja rude pa so še danes vidne v reki Idrijci. Živo srebro v reki Idrijci je tako posledica atmosferske depozicije, odnašanja prsti in erozije prežganih ostankov rude, kar se kaže v visokih koncentracijah v reki, rečnih sedimentih in Tržaškem zalivu. **M. Horvat** z Instituta Jožef Stefan in sodelavci so prikazali porazdelitev živega srebra v vodi, sedimentu in prsti v porečju Idrijce in Soče. Koncentracije totalnega živega srebra v reki Idrijci po rudniku narastejo približno 20-kratno v primerjavi s koncentracijami nad mestom. Koncentracije v Idrijci ostajajo visoke do izliva v Sočo, nato pa je opazen padec koncentracij po jezovih in predvsem Sočinem ustju. Koncentracije reaktivnega živega srebra, ki obsega raztopljeno plinasto in lahko reducirano anorgansko vezano živo srebro, kažejo podoben trend kot celotno živo srebro. Reaktivno živo srebro je značilno povezano z raztopljenim, kar kaže, da je njegov delež izpostavljen hitrim pretvorbam v vodi, nasprotno pa ni opaziti značilne povezave med celotnim in reaktivnim živim srebrom zaradi nizke reaktivnosti živega srebra, vezanega na delce. Koncentracije raztopljenega živega srebra so višje v Idrijci kot Soči, ponovno narastejo pa Sočinem ustju. Metil živo srebro kaže podoben trend kot celotno z najvišjimi koncentracijami pod mestom Idrijo, najnižjimi pred sotočjem Idrijce in Soče in povišanimi koncentracijami v akumulacijskih jezerih in ustju Soče, ki so pomembna mesta pretvorb. Porazdelitveni koeficienti med suspendiranim in raztopljenim živim srebrom so visoki in variabilni, kar kaže na njegovo močno vezavo na delce, ki je večja od metil živega srebra. Obstaja negativna povezava med porazdelitvenimi koeficienti in suspendirano snovjo. Delež metil živega srebra v celotnem živem srebru narašča v akumulacijskih jezerih in Sočinem ustju. V sedimentih Idrijce je koncentracija živega srebra najvišja pod mestom Idrijo, v sedimentih Soče pa so koncentracije nižje, razen v sedimentih akumulacijskih jezer. Povišane koncentracije metil živega srebra so vidne v sedimentih Idrijce po mestu Idriji in so nato nižje v Soči. V prsti so najvišje koncentracije v površinski plasti v bližini opuščenega metalurškega obrata, globlje so koncentracije nižje, kar kaže na recentno atmosfersko in rečno depozicijo. Koncentracije metil živega srebra so v prsti nižje kot v rečnih sedimentih, kar kaže na nizko hitrost metilacije. Višje koncentracije so opazne na vzpetinah zaradi različnih izvorov: živo srebro v gozdni prsti je predvsem posledica atmosferske depozicije, v nižini pa je posledica depozicije delcev cinabarita. Reaktivnost atmosferskega živega srebra je večja od delcev cinabarita ob reki, kar se kaže v povišani koncentraciji metil živega srebra, ki se ob močnem deževju spira v reko in nato v morje. Transport živega srebra je večinoma posledica hidrometeoroloških razmer v področju. **H. Biester** z Inštituta za geokemijo okolja iz Heidelberga (ZR Nemčija) in sodelavci so analizirali speciacijo živega srebra v prsti in sedimentih območja idrijskega rudnika. Najvišje koncentracije so bile zabeležene v starejših ostankih žganega cinabarita zaradi nizkih izkoristkov v metalurškem procesu v preteklosti. V rudi iz obdobja krede je predvsem samorodno živo srebro, v dolomitnih kamninah pa predvsem cinabarit. V žganih ostankih rude, mlajših od 200 let, je predvsem živo srebro, ki ni vezano v cinabaritu. Visoke koncentracije kovinskega živega srebra so posledica nepopolnega sežiga rude ali pa vezave na železov oksid. V mlajših ostankih je živosrebrov oksid. V prsti v bližini rudnika in ostankov rude je cinabarit, drugje pa je zaradi atmosferske depozicije emisij metalurškega procesa živo srebro vezano predvsem na organsko snov. V rečnih sedimentih Idrijce in Soče je viden padec koncentracij nizvodno, višje koncentracije so opazne v naplavinah kot v rečnih brzicah. V grobih delcih so visoke koncentracije živega srebra v obliki cinabarita, živo srebro v drobnih delcih pa je organsko vezano. V sedimentih Idrijce in Soče do izliva v morje je živo srebro vezano večinoma v cinabaritu. Živo srebro, ki ni v obliki cinabarita in je vezano v manjših delcih, se večinoma odplavlja v Tržaški zaliv, cinabarit, vezan v grobih delcih, pa ostaja v rečnih sedimentih. **M. Gosar** z Geološkega zavoda Slovenije in sodelavci so analizirali vsebnost živega srebra v mestnem in hišnem (na podstrešjih starih hiš) prahu ter prsti v Idriji in okolici. Oba analizna podatka se geografsko dobro ujemata, prav tako obstaja značilna povezava med obema podatkoma in višino, kar kaže, da je onesnaženje večinoma omejeno na dolino reke Idrijce. Najvišje koncentracije v prahu so ugotovili v bližini dimnika metalurškega obrata in zračnika rudnika v dolini Ljubevšce. **A. Gnamuš** z Ministrstva za šolstvo, znanost in šport in sodelavci so predstavili analize živega srebra in metil živega srebra v prsti in vegetaciji (gozdu) v območju Idrije in Podljubelja ter primerjalno v Ljubljani. Visoke koncentracije v območju Idrije so v zadnjem desetletju ostale približno konstantne, vzporedno z visokimi koncentracijami živega srebra v zraku. Koncentracije v vegetaciji so nižje kot v prsti, obe pa ostajata kljub zmanjšani emisiji živega srebra visoki in pomenita najpomembnejši vnos kovine v prehranjevalne verige. Visoke koncentracije živega srebra so opazne tudi v prsti in vegetaciji ob davno opuščenem rudniku v Podljubelju. Metil živo srebro se hitreje privzema v rastlinah kot celotno živo srebro, privzem obeh pa se zmanjšuje z naraščanjem pH in vsebnostjo organske snovi v zemlji. **T. Barkay** z Univerze Rutgers v New Jerseyu (ZDA) je predstavila molekularne in biokemijske raziskave mikrobnega potenciala volatilizacije Hg v ekosistemih Idrijce in Tržaškega zaliva. Bakterijska redukcija živega srebra (II) in metil živega strebra poteka z encimoma reduktazo (produkt gena *mer* A) in liazo (produkt gena *mer* B), ki sta del bakterijske odpornosti proti živemu srebru v operonu *mer*. Biosintezo obeh inducira Hg(II), in razgradnja metil živega srebra in redukcija Hg(II) sta odvisni od koncentracije Hg(II) v okolju žive bakterijske celice. Geni *mer* so močno zastopani v mikrobni biomasi v Idrijci in Soči, kjer je pojavljanje *mer* B obratno sorazmerno s koncentracijo metil živega srebra in biološke porabe Hg(II). Obstaja povezava med izvorom živega srebra v Idrijci in prisotnostjo mikrobnih genov *mer*, kar zmanjšuje koncentracijo Hg(II) v rečni vodi, ki se izliva v Tržaški zaliv. *Biološka volatilizacija Hg(II), ki je aktivna v Idrijci, je* lahko bioremediacijski proces zmanjševanja nastanka metil živega srebra v Tržaškem zalivu. Združbe makroinvertebratov, ki jih pogosto uporabljajo za določanje vpliva polutantov v vodah, je **E. B. Major** z Univerze na Alaski v Anchorageu (ZDA) uporabila v reki Idrijci za določanje vpliva živega srebra na vodne združbe in kopičenje v organizmih, ki omogočajo vnos živega srebra v prehranjevalno verigo. Koncentracija celotnega in metil živega srebra v makroinvertebratih je močno povišana v bližini mesta Idrije. Nato nizvodno pada in je izvor za kopičenje živega srebra v ribah. **A. B. Kobal** iz Rudnika živega srebra v Idriji in sodelavci so predstavili vpliv rudnika živega srebra na zdravje rudarjev in prebivalcev Idrije, ki so bili (predvsem rudarji) izpostavljeni elementemu živemu srebru, prahu in ionizirajočemu sevanju (radonu). Najvišja koncentracija elementnega živega srebra je bila v bližini metalurškega obrata. Število zastrupitev, ki je bilo po drugi svetovni vojni visoko, je nato padalo, čeprav so rudarili v nahajališčih, bogatih s samorodnim živim srebrom. Analize so pokazale subakutne in kronične zastrupitve z živim srebrom, ki so se kazale v drhtavici, orofaringelnem sindromu, eritizmu in proteinurei. Analize umrlih delavcev rudnika so pokazale višje koncentracije živega srebra (in selena) kot v prebivalcih Idrije, kopičilo pa se je posebno v endokrinih žlezah, ledvicah, jetrih in možganih. Koncentracije živega srebra v prebivalcih Idrije so v splošnem precej višje kot v prebivalcih nekontaminiranih območij, saj je okolje s svojo prstjo, zrakom, vegetacijo in ribami močno kontaminirano z živim srebrom. Ostanki prežgane rude, na katerih so zgrajene hiše, vsebujejo še visoke koncentracije nuklidov ^{238}U, ^{226}Ra, ^{232}Th in ^{40}K. Povečano je število rakavih obolenj in obstaja možnost močne povezave med anorganskim živim srebrom in nastankom raka na jetrih. Dolgotrajni vpliv živega srebra na centralni živčni sistem je viden v razdražljivosti, nespečnosti, depresiji in drhtavici.

Tržaški zaliv

J. Faganeli z Morske biološke postaje Piran Nacionalnega inštituta za biologijo in Univerze v Ljubljani ter sodelavci so prikazali porazdelitev celotnega in raztopljenega živega srebra in metil živega srebra v vodah Tržaškega zaliva. Visoke koncentracije celotnega živega srebra so omejene na območje izliva reke Soče, medtem ko se koncentracije raztopljenega živega srebra manj razlikujejo od drugih (nekontaminiranih) območij v Jadranu. Značilni povezavi med celotnim in raztopljenim živim srebrom in slanostjo kažeta na skupni rečni izvor obeh zvrsti, med celotnim in reaktivnim pa, da obstaja stalni delež celotnega živega srebra, ki je izpostavljen biogeokemijskim spremembam. Višje koncentracije celotnega in raztopljenega živega srebra in celotnega in raztopljenega metil živega srebra pri dnu so posledica remobilizacije in resuspenzije z dna. To potrjuje visoka hitrost sedimentacije suspendiranega živega srebra v zalivu, ki je povezana s sedimentacijo celotne suspendirane snovi. Nihanja v vsebnosti celotnega in metil živega srebra v mezozooplanktonu so posledica časovnih sprememb biomase in vrstne sestave. **S. Covelli** z Univerze v Trstu (Italija) in sodelavci so predstavili porazdelitev živega srebra v sedimentih Tržaškega zaliva, ki je, ob Kaštelanskem zalivu, najvišja v Jadranskem morju. Pozornost zbujajo visoke koncentracije ob izlivu Soče, ki se razširjajo proti zahodu ob italijanski obali. Živo srebro v delcih cinabarita se deponira pretežno v območjih peščenega dna ob izlivu Soče in severne obale zaliva. V osrednjem delu zaliva je živo srebro vezano predvsem na drobne glinene delce in v organskih kompleksih. Delež organsko vezanega živega srebra se povečuje proti sredini zaliva, vzporedno z večjim deležem drobnih delcev v sedimentu. Vsebnost metil živega srebra se povečuje z oddaljenostjo od izliva Soče (znižanjem vsebnosti celotnega živega srebra) in povečanim deležem glinenih delcev. Koncentracije celotnega raztopljenega in metil živega srebra v pornih vodah v sedimentu so najvišje v jesenskem obdobju zaradi prehoda med hitro redukcijo sulfata v poletnem obdobju in jesensko nižjo mikrobno aktivnostjo (zaradi nižjih temperatur), kar omogoča intenzivnejše pretvorbe, tokove in akumulacijo na meji sediment-voda. Daljša jedra sedimenta iz Tržaškega zaliva kažejo na močno povišane koncentracije v vrhnjih plasteh kot posledica proizvodnje živega srebra v Idriji (največja leta 1913). **M. E. Hines** z Univerze na Alaski v Anchorageu (ZDA) in sodelavci so preučevali nastanek in razgradnjo metil živega srebra v sedimentih Tržaškega zaliva. Z reko vnešeni cinabarit se raztaplja v stiku s povišanimi koncentracijami sulfida v pornih vodah in živo srebro se metilira in nato z aerobnimi in anaerobnimi bakterijami demetilira. Oba procesa, ki potekata v sedimentu celotnega zaliva, vodijo predvsem sulfat reducirajoče bakterije. Njun odsev so podobne koncentracije raztopljenega in metil živega srebra v pornih vodah z različnih odvzemnih mest v zalivu. Oba procesa sta sklopljena in najhitrejša v poletnem obdobju. Demetilacija poteka večinoma oksidativno in nastali produkt je CO_2. Pozimi je pomemben produkt tudi CH_4, ki nastaja reduktivno z bakterijskim operonom *mer*. **A. Brambati** z Univerze v Trstu (Italija) in sodelavci so prikazali rezultate kontaminacje sedimentov in organizmov z živim srebrom v Maranski in Gradeški laguni, ki je v vzhodnem delu pod vplivom vnosa reke Soče. Viden je padec koncentracij živega srebra v sedimentu v smeri proti zahodu z višjimi koncentracijami v plasti pod površino. Izjema je osrednji del Maranske lagune, kjer je povišana koncentracija živega srebra še posledica lokalne klor-alkalne industrijske dejavnosti. Padec vsebnosti živega srebra v vodnih rastlinah in živalih sledi padcu koncentracij v sedimentu. V morski travi *Zostera marina* se večina kovine akumulira na površini. Višje koncentracije živega srebra se kopičijo v višjih trofičnih nivojih. V ribah, tudi gojenih v marikulturi, se kopičenje poveča z velikostjo (starostjo). Povišane vsebnosti so bile končno ugotovljene v pticah in laseh lokalnih prebivalcev, ki so se hranili predvsem z ribami. **D. Žagar** in **A. Širca** z Univerze v Ljubljani sta opisala masno bilanco živega srebra v Tržaškem zalivu. Vnos s Sočo je daleč najpomembnejši vnos v zaliv in obsega 1,5 tone letno, od tega 99,5% v suspendirani obliki. Raztopljeno metil živo srebro sestavlja le 1,5% celotnega raztopljenega živega srebra v vnosu. Velika večina vnešenega živega srebra sedimentira in ostaja trajno deponirana na dnu Tržaškega zaliva. **F. Barbone** z Univerze v Vidmu (Italija) in sodelavci so v preliminarni epidemiološki študiji prehranjevanja prebivalcev z ribami in vsebnosti živega srebra v laseh in materinem mleku in dojenčkih v obalnem območju severovzhodne Italije pokazali, da zaradi razmeroma majhne porabe rib v prehrani visoke koncentracije v okolju ne vodijo do povišanih vsebnostih živega srebra v preučevani populaciji.

Primerjave

V primerjavah med posameznimi predeli, kontaminiranimi z živim srebrom, so **P. Higueras** z Univerze Castilla-La Mancha v Almadenu (Španija) in sodelavci prikazali onesnaženje zemlje v bližini največjega rudnika živega srebra, Almadena (Španija), na svetu, ki je posledica deponij prežganih ostankov rude in metalurških obratov. Najvišje vsebnosti v prsti so v območju pH=7 zaradi tam obstoječih karbonatov. V prsti je živo srebro trdno vezano v cinabaritu in v huminskih kislinah. **E. A. Bailey** z Geološkega zavoda ZDA v Anchorageu in sodelavci so preučevali pretvorbe živega srebra v zemlji v bližini dveh rudnikov na Alaski, kjer so koncentracije celotnega Hg(II) in metil živega srebra visoke in obstaja obratna zveza med deležem metil živega srebra in celotnim živim srebrom ter metil živim srebrom in organskim ogljikom v vzorcih. Najvišji potencial demetilacije je v vzorcih z visokimi vsebnostmi celotnega živega srebra in pri reduktivnem procesu nastajata Hg(II) in CH_4, pri oksidativnem pa še CO_2. Hitrost metilacije je nižja. **J. K. Schaefer** in sodelavci z Univerze Rutgers iz New Jerseya (ZDA) so pokazali, da je povišana akumulacija metil živega srebra v razmeroma nekontaminiranem kislem jezeru glede na bolj onesnaženo kislo jezero povezana s obstojem bakterijskega gena *mer*, nastankom encima liaze in intenzivnejšo razgradnjo metil živega srebra. Modeliranje porazdelitve živega srebra v zelo onesnaženi reki Carson (Nevada, ZDA), ki je posledica suspendiranega živega srebra, na kar vplivata erozija in transport delcev, so predstavili **J. J. Warwick** z Univerze Gainesville na Floridi (ZDA) in sodelavci. Model je pokazal, da koncentracija anorgansko vezanega živega srebra narašča nizvodno z naraščajočim pretokom reke. Primerjava, ki so jo predstavili **H. Bilinski** in sodelavci z Inštituta Rudjer Bošković iz Zagreba (Hrvaška), in sicer med Tržaškim zalivom in Kaštelanskim zalivom pri Splitu, kamor so se 40 let izlivale odplake lokalne klor-alkalne industrije, kaže podobne koncentracije celotnega živega srebra v sedimentu, a višje koncentracije metil živega srebra. Celotno živo srebro v sedimentih Kaštelanskega zaliva je po podatkih **S. Niessen** z Univerze v Lilllu (Francija) in sodelavcev povezno z vsebnostjo karbonata, metil živo srebro pa z vsebnostjo organskega ogljika in sulfida. Kot je ugotovil **T. Zvonarić** z Inštituta za oceanografijo in ribištvo v Splitu (Hrvaška), je kontaminirani sediment izvor celotnega in metil živega srebra v školjkah (dagnje), ki se akumulira pretežno v prebavnem traktu. **C. Trombini** z Univerze v Bologni (Ita-



Kroženje živega srebra v območju Idrije, Soče in Tržaškega zaliva

lija) in sodelavci so predstavili onesnaženje zaščitene obalne lagune Pialassa Baiona (Ravenna, Italija) z živim srebrom, ki je posledica lokalne klor-alkalne industrije. Koncentracije celotnega živega srebra v sedimentu so visoke in zaradi resuspenzije sedimenta in cvetenja bentoških makroalg se polutant razširja po laguni. Živo srebro se vključuje v prehranjevalno verigo (školjke). V sedimentu z nižjo vsebnostjo celotnega živega srebra so vidne višje koncentracije metil in kovinskega živega srebra, kar kaže, da je živo srebro v manj kontaminiranih sedimentih bolj izpostavljeno biološkim pretvorbam. Analize speciacije živega srebra v Jadranskem in Sredozemskem morju, ki so jih predstavili **M. Horvat** z Instituta Jožef Stefan in sodelavci, so pokazale, da so koncentracije celotnega in celotnega metil ter celotnega raztopljenega in raztopljenega metil živega srebra v primerjavi s Tržaškim in Kaštelanskim zalivom zelo nizke. V odprtih vodah je živo srebro zelo reaktivno in nastajata metil in raztopljeno plinasto živo srebro. V onesnaženih obalnih predelih se nastale reaktivne zvrsti vežejo na raztopljene organske spojine. Raztopljene plinaste živosrebrove spojine se v površinski plasti morja fotokemijsko oksidirajo, delno pa prehajajo v atmosfero.

Zaključki

Na okogli mizi, ki jo je vodil **P. Stegnar** z Instituta Jožef Stefan, smo pregledali manjkajoče podatke in določili smeri prihodnjih raziskav. Izhlapevanje živega srebra v atmosfero predstavlja glavno transportno pot za aktivno kroženje živega srebra in disperzijo v manj kontaminirana območja. Rezultati meritev v kontaminiranih rudniških območjih so pokazali, da je živo srebro v zraku močno povečano tudi po večletnem zaprtju rudnikov. Na območju Idrije je pogosto presežena dovoljena koncentracija živega srebra v zraku (0,05 $\mu g\ m^{-3}$), kar dodatno obremenjuje prebivalce Idrije. Koncentracije v zraku so zlasti povečane v sončnem in toplem vremenu. Pomembni izvori živega srebra v zraku so topilniški dimniki, peči ter območja v neposredni okolici teh objektov. Prezračevanje rudniških rovov prav tako predstavlja pomemben izvor živega srebra v zraku, kar je zlasti pomembno tudi v Idriji. V prvi fazi remediacije je torej potrebno dokončno odstraniti najpomemnejše izvore živega srebra v zraku, kar je bilo v Idriji deloma narejeno že v prvih letih po prenehanju delovanja rudnika. Mnogo težje je očistiti kontaminirano prst, ki je prav tako pomemben izvor živega srebra v zraku. Rastlinski pokrov lahko bistveno zmanjša izhlapevanje živega srebra v zrak, prav tako pa zmanjšuje disperzijo kontaminiranega prahu. Pomembno je tudi kontrolirati kontaminacijo rudniških objektov, katerih namembnost se je spremenila v komercialno uporabo. Na območju Idrije so meritve živega srebra v zraku redke, prav tako ni podatkov o izmenjavi živega srebra med prstjo in zrakom. Ti podatki so nujno potrebni za oceno masne bilance v ožjem in širšem območju Idrije. V nadaljevanju raziskav, ki obravnavajo vplive na zdravje ljudi na tem območju, je zato potrebno v prvi vrsti izdelati modele za oceno izpostavljenosti in identificirati najbolj kritične populacije. Na osnovi teh podatkov bo možno izvesti ukrepe za izboljšanje stanja.

Rezultati raziskav so potrdili, da poteka na območju Idrije, Idrijce in Posočja aktivni prenos živega srebra iz kontaminiranih območij v okolici Idrije ter iz kontaminiranih rečnih naplavin do Tržaškega zaliva, kjer se živo srebro dokončno odlaga v morskem sedimentu. Gibanje morja v zalivu odnaša živo srebro vezano na suspendirane delce proti zahodu. Za boljše razumevanje biogeokemijskega kroženja v rečnem in morskem ekosistemu obstaja danes cela vrst neznank, ki jih bo potrebno razrešiti. Na območju Idrije in Posočja je potrebno nadaljevati s preučevanjem transporta in depozicije živega srebra v rekah, rečnih naplavinah in v prsti ter akumulacijo živega srebra v prehranjevalnih verigah kopenskih in vodnih ekosistemov. Neznane ali le slabo poznane so pretvorbe različnih zvrsti živega srebra v vodi, ki vključujejo kovinske ione, metil in dimetil živo srebro ter biološko »uporabno« živo srebro. Posebno pozornost bo potrebno posvetiti procesom pretvorb v akumulacijskih jezerih in estuariju Soče, kjer prihaja do intenzivnih biogeokemijskih pretvorb. V rečnem sistemu je torej potrebno najti odgovor na številna vprašanja, kot so ocena transporta v različnih hidroloških pogojih, kemijske oblike živega srebra v sedimentu in njihova reaktivnost, ter s tem povezanih procesov pretvorb v sedimentu, rečnih naplavinah in vodi, posebej še v akumulacijah treh hidroelektrarn. V morskem ekosistemu je prav tako potrebno proučiti vplive bioturbacije na izmenjavo Hg med sedimentom in vodo ter zlasti vpliv občasnega pomanjkanja kisika na dnu Tržaškega zaliva. Tovrstne študije so pomembne, ker predstavljajo osnovo za izdelavo zanesljivih modelov za simulacijo procesov in napovedovanje koncentracij živega srebra v morskih organizmih. Kombinacija okoljskih modelov s socialno-ekonomskimi scenariji lahko omogoči pravilno izrabo prostora in razvojne možnosti.

Nujno potreben je multidisciplinaren pristop k razumevanju obravnavane problematike na območju Idrije, Posočja in Tržaškega zaliva. Rezultate temeljnih raziskav, ki vključujejo predvsem biološke in geokemijske procese v različnih naravnih okoljih, je potrebno integrirati v pripravo političnih odločanj in upravljanja s tem področjem. Pri izdelavi razvojnih načrtov je potrebno omeniti predvsem nekatere pomembne ekonomske dejavnosti, kot so ribištvo in marikultura, pomorski promet in s tem povezano infrastrukturo, izrabo tal na kontaminiranih območjih Idrije in Posočja ter izrabo vodnih virov za pridobivanje električne energije. Vse te dejavnosti lahko bistveno prispevajo k remobilizaciji nakopičenega živega srebra in s tem povzročijo veliko okoljsko in zdravstveno škodo ter zavrejo uspešno delovanje in razvoj teh dejavnosti. K temu nas bo prisilila tudi nova evropska zakonodaja, ki uvršča živo srebro med pomembne okoljske onesnaževalce. Priprava zakonodaje sloni predvsem na novih ugotovitvah o še varnih dnevnih dozah živega srebra, ki ga ljudje v glavnem privzamemo z uživanjem hrane, zlasti rib, ki pri nas vsebujejo najvišje koncentracije. Živo srebro v ribah je v glavnem prisotno kot metil živo srebro, ki spada med najbolj toksične spojine, in prizadene predvsem možgane v obdobju nastanka v zarodku. Za oceno tveganja je Ameriška okoljska agencija (US EPA) uporabila referenčno dozo (RfD), pri kateri še ne zaznamo nobenih kvarnih vplivov te toksične spojine. Referenčna doza znaša 0,1 µg metil živega srebra na kilogram telesne teže dnevno. Ta doza je lahko hitro presežena ob pogostem uživanju rib, ki so kontaminirane z živim srebrom. Za območje porečij Idrijce in Soče ter Tržaškega zaliva je znano, da so koncentracije živega srebra v ribah povišane in pogosto presegajo 0,2 mg/kg sveže teže. V nekaterih primerih koncentracije dosegajo celo 1 mg živega srebra na kg. Oseba, ki zaužije tedensko 250 g rib (2 obroka tedensko) s koncentracijo 0,2 mg/kg, že presega RfD. Ob višjih koncentracijah Hg v ribah pa je ta doza pogosto presežena že ob enem samem obroku na teden. V primeru bolj pogostega uživanja rib je potrebno uvesti priporočila zlasti za najbolj občutljivo populacijo, v katero spadajo predvsem nosečnice in otroci.

Na kratko lahko povzamemo, da je delavnica osvetlila številne pomanjkljivosti v poznavanju vplivov živega srebra na okolje in zdravje ljudi na ožjem in širšem območju Idrije in Tržaškega zaliva. Postavili smo nove temelje za sodelovanje med raziskovalci različnih strok, ki bodo v nadaljnih letih bistveno prispevali k boljšemu razumevanju bioloških in geokemijskih procesov in remediacije. Vzporedno bo potrebno zasledovati vplive na človekovo zdravje tako v območju Idrije kot v Tržaškem zalivu.

Jadran Faganeli in Milena Horvat

3. MEDNARODNI KONGRES "EKOLOGIJA IN VARSTVO EVROPSKIH GOZDNIH SOV"

Med 12. in 15. oktobrom 2000 je bil v Nemčiji, v kraju St. Andreasberg (gorovje Harz), mednarodni kongres o sovah. Organizirala ga je delovna skupina največje nemške naravovarstvene organizacije NABU.

Kongres je potekal v kongresnem centru Sonnenberg - majhnem naselju z bivalnimi prostori, predavalnico, veliko kuhinjo in jedilnico. Center je bil zgrajen sredi gozda, 15 minut vožnje z avtomobilom od najbližje vasi. Organizacija kongresa je bila klasična, z dopoldanskimi in popoldanskimi predavanji ter predstavitvijo plakatov, ki je potekala v času med predavanji. Za večerno zabavo so poskrbeli v pivnici, ki pa je bila bolj podobna angleškemu *pubu* kot klasični nemški "nalivalnici s pivom".

Mednarodni del kongresa je potekal v sklopu 16. srečanja "sovologov" Nemčije, kar z drugimi besedami pomeni, da je bilo večina aktivnih udeležencev iz te države, vključno s svetovno znanimi strokovnjaki, kot sta dr. W. Scherzinger in dr. O. Schwerdtfeger. Sicer pa tudi mednarodni del udeležbe ni bil na odmet. Še posebej močna je bila ekipa iz Finske, v kateri so zbujali pozornost vodilni strokovnjaki za sove, dr. E. Korpimäki, dr. H. Pietiäinen in P. Saurola. Kot gost je bil na kongresu navzoč tudi dr. I. Newton, Škot po rodu, ki pa že nekaj časa živi in službuje v Avstraliji. V zanimivem večernem predavanju nam je v sliki in besedi ilustriral stanje raziskovanja sov in drugih ptic na tej oddaljeni celini, kjer je stopnja raziskanosti občutno nižja kot v Evropi. Številna je bila tudi udeležba strokovnjakov iz vzhodne Evrope, od Čehov, Slovakov in Poljakov do Rusov in Belorusov, presenetljivo pa ni bilo nikogar iz Anglije in tudi iz povsem južnih evropskih držav - Italije, Grčije, Španije in Portugalske.

Največ prispevkov na kongresu je bilo o lesni sovi *(Strix aluco).* Ta vrsta je predvsem v zahodni Evropi hvaležen objekt raziskav. Recept za raziskave lesne sove, ki so ga ponujali številni prispevki, je preprost. V gospodarsko izčrpanih in oklėščenih gozdovih postaviš gnezdilnice, ki jih vrsta rada zasede, in že se zbirajo podatki. Nemški kolegi se, vsaj po številu prispevkov sodeč, največ ukvarjajo s koconogim čukom *(Aegolius funereus),* ki ima največjo populacijo v Nemčiji prav v okolici kongresnega centra. Čeprav so organizatorji obljubljali tudi obisk čukovih gnezdišč, pa je zaradi vremena (ali pa morda preveč piva!) nočni izlet pozneje padel v vodo. Zelo poučne, čeprav metodološko nekoliko slabše so bile predstavitve kozače, s katero se ukvarja kar nekaj vzhodnoevropskih strokovnjakov. V nasprotju s finskimi kozačami, ki gnezdijo le še v umetnih gnezdilnicah, smo od njih izvedeli marsikaj o naravnih gnezdih. Nekaj je bilo tudi prispevkov o dolgoročnih, deset, dvajset in tudi trideset let trajajočih gnezditvenih in prehranjevalnih popisih sov. Na kongresu je bilo veliko slišati tudi o ogroženosti lesne sove in male uharice. Ali sta vrsti v Evropi že ogroženi ali še ne? Mnenja so bila zelo deljena. Zelo malo ali celo nič je bilo prispevkov o veliki *(Bubo bubo)* in močvirski uharici *(Asio flammeus)* ter seveda o pegasti sovi *(Tyto alba),* ki je ne štejemo med gozdne.

V Evropi so srečanja strokovnjakov, ki se ukvarjajo s sovami, dokaj redka in neredna. Prvo je bilo leta 1990 v Švici, drugo leta 1992 na Škotskem. Kje in kdaj bo naslednje, ne ve še nihče.

Davorin Tome

OCENE
RECENSIONI
REVIEWS

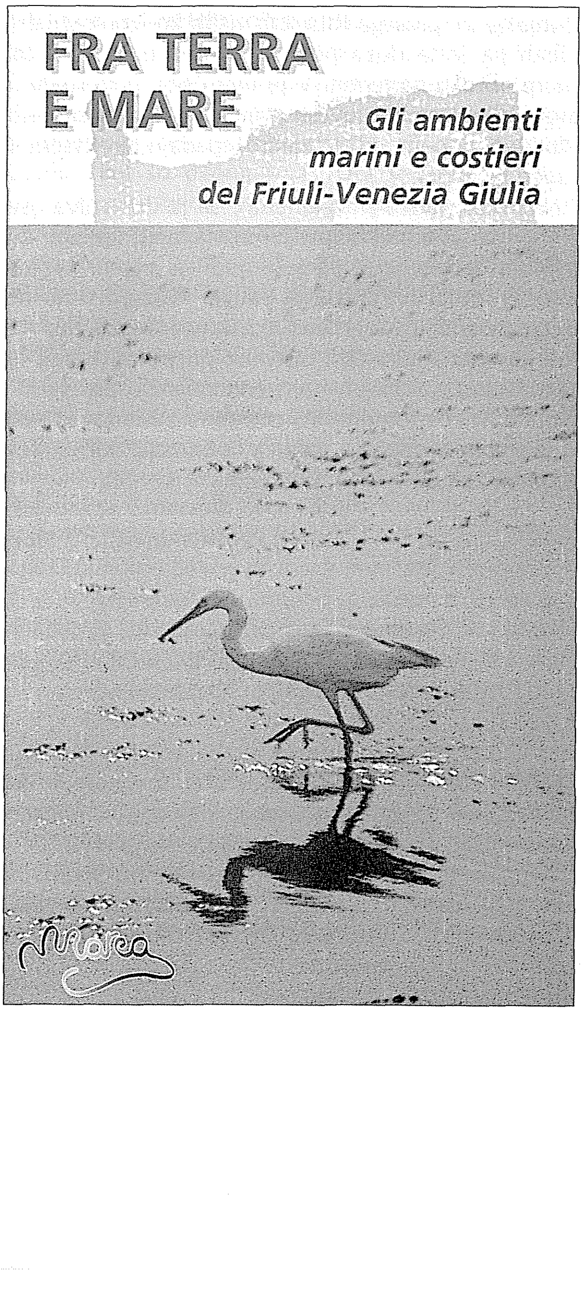
Colla Andrea, Costantini Marco, Gherdol Santino, Odorico Roberto, Oriolo Giuseppe, Pisa Giulia, Poldini Livio, Spoto Maurizio, Utmar Paolo, Verginella Laura, Vidali Marisa & Visintin Gianna: FRA TERRA E MARE. GLI AMBIENTI MARINI E COSTIERI DEL FRIULI-VENEZIA GIULIA. Tipografia Villaggio del Fanciullo, Trieste, 2000; 182 pp.

A un anno dalla prima pubblicazione della collana "Marea" è uscito il secondo taccuino naturalistico dedicato agli ambienti costieri strettamente influenzati dal mare. Nel precedente volume gli autori avevano introdotto più o meno tutti gli ambienti marini e costieri del Friuli-Venezia Giulia, mentre nel presente, intitolato *"Fra terra e mare"*, hanno approfondito la descrizione dei piani sopralitorale (inumidito dagli spruzzi delle onde) e mesolitorale (compreso tra l'alta e la bassa marea). Ottima scelta, visto che proprio la fascia costiera caratterizzata da questi due piani è la prima e l'unica accessibile anche a coloro che non sanno nuotare. Per osservare gli organismi che popolano il mesolitorale, infatti, non serve bagnarsi poi molto.

Nel primo capitolo del libro gli autori ci portano a conoscere il paesaggio della costa bassa, tipicamente lagunare, che comprende le piane di marea, i cordoni litoranei, le spiagge e le barene. Nel testo non troviamo solo descrizioni dettagliate di fauna e flora, ma anche informazioni sulle associazioni vegetali tipiche di alcuni importanti siti naturalistici. Lo sguardo del lettore viene inevitabilmente rapito dai bellissimi disegni e fotografie.

Procedendo nella lettura, ci si imbatte nel paesaggio della costa rocciosa, suddivisa in formazioni calcaree e flyschoidi. Queste due unità presentano differenti caratteristiche litologiche e mineralogiche, *"determinando configurazioni differenti del territorio sia a grande che a piccola scala"* (p. 70). La costa calcarea e quella flyschoide presentano ampie diversità pure nei popolamenti animali e vegetali, visto che non tutti i tipi di substrato possono vantare la stessa ricchezza di microambienti. A tal proposito gli autori si soffermano sulle abitudini di vita dei blennidi (comunemente detti bavose), piccoli pesci territoriali poco conosciuti al pubblico in quanto specie ittiche non pregiate, ma estremamente interessanti per gli appassionati di etologia. Durante il periodo riproduttivo, i maschi di queste specie occupano le fessure delle rocce (anche i fori dei molluschi scavatori, come il dattero di mare) e sfoggiano colorazioni accese al fine di persuadere le femmine ad entrare nella tana, per deporvi le uova. Il capitolo termina con le pagine dedicate alla costa flyschoide ed alle rupi a mare, con una nota particolare sulla centaurea fronzuta *(Centaurea kartschiana)* che cresce solo sulle rocce calcaree tra Duino ed Aurisina.

La seconda parte del libro viene dedicata agli *"abitanti fra terra e mare"*, ossia a quegli organismi che hanno bisogno di un'emersione continua o che sopportano emersioni prolungate, quindi adattati a condizioni estreme. Ottimo il contributo botanico, che porta il lettore a conoscere la flora e la vegetazione di spiagge e barene, come le piante psammofile (che crescono spontanee su terreni sabbiosi litoranei) e quelle alofile (che vivono in terreni salati). Si concludono qui le pagine dedicate alla flora, mentre si torna a parlare di fauna con una parentesi incentrata sugli invertebrati. Insetti e crostacei hanno raggiunto un equilibrio perfetto sulle rive, mentre dominano i primi sulla terraferma e i secondi in acque più profonde. I pesci residenti nella zona di marea, come i già menzionati blennidi, hanno dovuto sviluppare caratteristiche particolari per contrastare la forza delle onde, come una taglia corporea ridotta e organi finalizzati all'adesione al substrato. Anche in questo sottocapitolo non mancano interessanti note etologiche.



Il libro si conclude dando ampio spazio agli uccelli, che rappresentano la componente animale più evidente delle zone costiere. Con l'ausilio di accurati disegni vengono descritte le abitudini alimentari, riproduttive e migratorie dell'avifauna della costa bassa e della costa rocciosa. Immancabile in appendice l'utilissimo glossario.

Ricordiamo che al programma "Marea" (progetto multimediale di divulgazione e di ricerca per la conservazione del territorio regionale) collaborano la Riserva Naturale Marina di Miramare - WWF Italia, l'Università degli Studi di Trieste (Dipartimento di Biologia), il Museo di Storia Naturale di Trieste e la Regione Autonoma Friuli-Venezia Giulia - Azienda dei Parchi e delle Foreste regionali.

Visto che "squadra vincente non si cambia", auguriamo all'affiatato staff di autori di continuare a regalarci almeno un volume all'anno.

Martina Orlando

KATALOG IZOBRAŽEVALNIH VSEBIN

Strokovne utemeljitve doživljajske pedagogike, jedrnato strnjene v izjavo "Povej mi in pozabil bom, pokaži mi in morda si bom zapomnil, vključi me in razumel bom", so, kot ponavadi, pricapljale k nam z zamudo, vendar so v nekaj letih pridobile izjemen vpliv, tako da smo priča silnemu razmahu doživljajsko pedagoških dejavnosti na vseh nivojih uradnega vzgojno izobraževalnega procesa. Otrokom je na voljo obilica bolj ali manj konvencionalnih šol v naravi, raziskovalnih, naravoslovnih in družboslovnih dni ter cela paleta različnih terenskih aktivnosti. V svetovnem merilu so takšne aktivnosti že dolgoročno uveljavljene in očitno je, da pri nas ne bo/ne sme biti drugače - kar pa ni le pozitivno. Kot rečeno, smo priča masovnosti - masovnost pa ni nič drugega kot trend. In ravno trendovstvo je največja potencialna nevarnost za prihodnost terenskih aktivnosti, saj marsikdo sili z glavo skozi zid v prepričanju, da je to aktivnost dovolj izpeljati (in se pri tem mogoče še pobahati), pozablja pa na kompleksnost zastavljenih ciljev in, predvsem, na varnost ter vpliv na okolje. Tu pa lahko začnemo govoriti o Katalogu izobraževalnih vsebin na zaščitenih območjih, Od Dragonje do izliva reke Soče, Navodila za pripravo in varno izvedbo - poleg zgovornega naslova še dva podnaslova. Avtorji očitno niso želeli nesporazumov in publikacije nikakor ne moremo vzeti v roke pomotoma, nasprotno, večina bo namensko toliko raje segla po njej. Čeprav v Sloveniji ni izšlo veliko del s to ali sorodno tematiko, pa spet ne moremo trditi, da česa podobnega še nimamo. Tako radovljiška Didakta kot Ministrstvo za šolstvo in šport sta izdala več del, ki se ukvarjajo s terenskimi raziskovalnimi deli in vajami in so do sedaj pomenila pomoč pri organizaciji, vendar pa so puščala tudi precejšnje organizacijsko - vsebinske luknje, ki so jih akterji (učitelji, vaditelji, organizatorji) bolj ali manj kompetentno zakrpali. Vsekakor so to dobro izpeljali le tisti z bogatimi izkušnjami in zagotovo bo izkustvo največja odlika tudi v prihodnje - bo pa s Katalogom vsem drugim bistveno lažje. Kljub naslovu publikacije pa ravno izobraževalne vsebine niso največja odlika tega dela. Že malce zagnan učitelj lahko hitro razčisti dileme okoli učnih vsebin, smotrov in metod dela na terenu; je pa nedvomno veliko bolj ugodno, če so le-te zbrane na enem mestu, sploh pa, ker so razdeljene tudi po območjih med Dragonjo in izlivom Soče (seveda pa pridejo v poštev na vseh podobnih lokacijah). Tudi opisi življenjskih okolij zaščitenih območij so dobrodošli, vendar tudi to ni adut kataloga. Nad nivo sorodnih publikacij se ta Katalog dvigne v delu, ki obravnava varnost, in sicer varnost udeležencev, ravno tako pa varnost okolja. Obširna navodila za pripravo varnostnega načrta so povzeta iz tridesetletnih izkušenj univerze v Princetonu na področju "Outdoor Activities" in so prava osvežitev v primerjavi z drugimi varnostnimi predpostavkami, do sedaj uporabljanimi v Sloveniji, ki slonijo na togih načelih evropske šole doživljajske pedagogike, predvsem angleške in nemške. Navodila so uporabna za izdelavo kakršnegakoli varnostnega načrta. Ka talog je nedvomno nepogrešljiva pomoč pri organizaciji vseh dejavnosti na na-

ših obalnih zaščitenih območjih, prav tako pa je uporaben za dejavnosti kjerkoli, naj bo to območje zaščiteno ali ne, prav tako pa si pomagamo z njim tudi pri kopici drugačnih aktivnosti. Če bi Katalog moral oceniti po šolsko, bi dobil *cum laude* 5+.

Dag Kleva

ATLANTE DEGLI UCCELLI SVERNANTI IN CAMPANIA

Prvi atlas prezimujočih ptic je izšel v Veliki Britaniji leta 1986. Slovenci smo svojega dobili razmeroma zgodaj, leta 1994. V Italiji ga sestavljajo postopno: po lombardijskem (1992) sta izšla še piemontsko-valdostanški (1996) in ligurski (1998). Pravkar pa se jim je pridružil še zimski atlas kampaniške regije. Campanio sestavljajo province: Napoli, Avellino, Benevento, Caserta in Salerno. Obsežno 540 strani obsegajočo publikacijo z naslovom *Atlante degli uccelli svernanti in Campania* je uredil Mario Milone, z letnico 1999 jo je izdalo Associazone Studi Ornitologici Italia Meridionale. V uvodnem delu različni avtorji pojasnujejo fenomen prezimovanja ptic, podrobno je predstavljeno zemljepisno ozemlje Campanie in njeno podnebje. Sledi poglavje o metodologiji popisovanja, štetja in kartiranja ptic. V posebnem poglavju so grafično predstavljeni rezultati raziskave. Najobsežnejši je seveda kartografski del knjige z izčrpnimi komentarji o vseh obravnavanih vrstah ptic. Knjiga ima dva dodatka: v prvem so obravnavane vrste, ki so bile opažene v manj kot treh kvadratih, v drugem vrste, ki v obdobju tega popisa niso bile evidentirane ali so jih popisali drugi avtorji. Sledijo tehtno poglavje o ekologiji prezimovanja ptic, geografski slovarček, povzetek v angleščini in obsežna bibliografija. Vmes je objavljenih nekaj barvnih fotografij najbolj tipičnih prezimovalnih habitatov.

Campania obsega 13.595 kvadratnih kilometrov, od tega je 56% ozemlja goratega. Najvišje gore so kljub bližini Sredozemskega morja pozimi zasnežene, saj je najvišji vrh Cervati visok kar 1899 m. Ozemlja odmaka več rek: Volturno (175 km), Calore (108 km), Sarno (24 km) in druge. Največje jezero Patria meri kar 190 ha. Morsko obrežje je dolgo 360 km, najbolj znan otok je Capri (1036 ha), ornitološko pa so pomembni tudi manjši vulkanski otoki.

Popisovanje je potekalo od 1. do 15. decembra (1989-94), od 1. do 31. januarja (1990-95) in od 1. do 15. februarja (1990-95). Štetje je bilo opravljeno po prirejeni točkovni metodi v 15-minutnih intervalih, kartografsko je bila uporabljena standardna mreža UTM v izmeri 10x10 km (179 kvadratov). Popisanih je bilo 161 vrst ptic, od tega 99 pevk in 62 nepevk. V celoti prezimuje v Campanii 182 vrst ptic, od tega 106 pevk in 76 nepevk. Najpogostejše vrste, navzoče v več kot 90% vseh kvadratov, so: ščinkavec, taščica, italijanski vrabec, lišček in kos. Za naše prevladujoče srednjevropsko gledanje so v tem atlasu najbolj zanimivi podatki o bolj ali manj rednem prezimovanju nekaterih pri nas izrazitih selivk na sredini Apeninskega polotoka. Takšne vrste so brez dvoma: veliki skovik, divja grlica, kukavica, repaljščica, vijeglavka, vrbja listnica, poljski škrjanec, breguljka, rjava cipa, rdečeglavi kraljiček, sivi muhar, plotni in črnoglavi strnad.

Kljub regionalnemu značaju tega zimskega atlasa najdemo v njem tudi veliko drugih in, kar se zdi najbolj pomembno, ažurnih podatkov o ornitofavni celotne Italije.

Iztok Geister

NOVA ORNITOLOŠKA REVIJA: ORNITHOLOGIA ALGIRICA

Institut National Agronomique iz El-Haracha v Alžiru je začel izdajati ornitološko revijo v francoskem jeziku z imenom Ornithologia Algirica. Ureja jo uredniška trojka: Doumandji Salaheddine, Bazis Belkacem in Souttou Karim, vsi z nacionalnega kmetijskega inštituta. Po napovedi naj bi izšli dve številki na leto. Zelo skromno oblikovana revija, ki na pogled učinkuje kot skripta, se odlikuje s kvalitetno vsebino. Prva številka prinaša štiri znanstvene članke na temo prehranske ekologije ptic. V članku o prehrani mladičev navadne postovke *Falco tinnunculus* lahko preberemo, da je bil v inštitutskem parku v El Harrachu v letu 2000 njen najpomembnejši plen (57%) križanec med domačim in španskim vrabcem *Passer domesticus* x *P. hispaniolensis*. Ta plen je odtehtal 80% biomase. Preostali plen so sestavljale večinoma žuželke. V raziskavi je bilo upoštevanih 39 izbljuvkov. V ruralnem okolju je bila analiza izbljuvkov navadne postovke bolj običajna: 64,5% so zavzemale žuželke, med njimi so z 39% prevladovale kobilice. Delež ptic je znašal le 5,5%, vendar so križanci med domačim in španskim vrabcem tudi tukaj odtehtali kar precejšen delež biomase (41%). V kraju Dergana so raziskovalci v poznem poletju zbrali 29 izbljuvkov odraslih postovk. V okolici jezera Ichkeul pa so raziskovalci analizirali 59 izbljuvkov čuka *(Athene noctua)*. V jesenski prehrani so prevladovale žuželke (88,5%), glodalci pa so zavzemali le 6%.

V regiji Boudouaou pa so raziskovalci jeseni analizirali izbljuvke kravje čaplje *(Bubulcus ibis)*, 10 v septembru in 10 v oktobru. Tako ločeni izbljuvki so se razlikovali po velikosti in po številu ter sestavi plena. Vendar so v obeh mesecih prevladovali kožokrilci Hymenoptera (38 oz. 46%) in hrošči Coleoptera (31 oz. 38%).

Vse prispevke v prvi številki nove alžirske in s tem tudi nove mediteranske ornitološke revije so napisali domači avtorji, ki se poklicno ukvarjajo z aplikativno ornitologijo.

Iztok Geister

KAZALO K SLIKAM NA OVITKU

SLIKA NA NASLOVNICI: Posnetki satelita Landsat 5-TM 21. junija 2000 ob 9.30. Uporabljeni so bili trije pasovi v vidnem delu spektra (rdeča, zelena, modra; pasovi 3, 2, 1). (Avtor: B. Petelin, izdelano na Morski biološki postaji Piran, Nacionalni inštitut za biologijo)

Slika 1: V soncu ožarjeni solinski bazeni v Krajinskem parku Sečoveljske soline. Za zdaj so Sečoveljske soline edino slovensko močvirje na seznamu ramsarskih lokalitet (Foto: D. Podgornik)

Slika 2: Mala bela čaplja *(Egretta garzetta)* je najpogostejša vrsta čapelj na jadranskih mokriščih. (Foto: T. Makovec)

Slika 3: Po novejših podatkih naj bi v hrvaškem delu Jadranskega morja gnezdilo okoli 60 parov sredozemskih sokolov *(Falco eleonorae)*. V svetovnem merilu je ena izmed redkejših ujed, saj je svetovna populacija ocenjena na nekaj več kot 6000 parov. (Foto: D. Ristow)

Slika 4: Slikovite starodavne soline na otoku Gozo, Malta. Število solin se je v zadnjih desetletjih v Sredozemlju močno zmanjšalo. (Foto: I. Škornik)

Slika 5: Letalski posnetek opuščenega dela Sečoveljskih solin, imenovanega Fontanigge. Sredi posnetka je kanal Giassi, kjer je tudi muzej solinarstva. (Foto: D. Podgornik)

Slika 6: Vodomec *(Alcedo atthis)* se na območju Sečoveljskih solin pojavlja skoraj vse leto, le spomladi ga ni. Tedaj ga najdemo višje ob Dragonji, kjer gnezdi v značilnih rovih v rečni brežini. (Foto: T. Makovec)

Slika 7: Papagajevka *(Sparisoma cretense)* je bila v vzhodnem Jadranu prvič zabeležena šele leta 2000. Dokumentiranje te vrste v okolici Palagruže je vnovičen primer pojavljanja toploljubnih vrst v Jadranu v zadnjih letih. (Foto: B. Furlan)

Slika 8: Sinje okno na otoku Gozo (Malta) je izjemen biser nedotaknjene sredozemske narave. (Foto: I. Škornik)

INDEX TO PICTURES ON THE COVER

FRONT COVER: Pseudo-natural colour composite of the Landsat 5-TM image from 21 June 2000, 9:30 am. Three spectral bands (3/7; RGB = bands 3, 2, 1, saturation stretched). (Author: B. Petelin; made at the Marine Biology Station Piran, National Institute of Biology)

Fig. 1: Salt-pan basins lit up by golden sunlight in the Sečovlje Salt-pans Landscape Park. The pans constitute the only Slovene wetland so far appearing on the list of the Ramsar sites. (Photo: D. Podgornik)

Fig. 2: Little Egret *(Egretta garzetta)* is the most common heron occurring at the Adriatic wetlands. (Photo: T. Makovec)

Fig. 3: According to the recent data, some 60 pairs of Eleonora's Falcons are allegedly breeding in the Croatian part of the Adriatic. This bird of prey is one of the rarest world-wide, for its world population is estimated only at a little more than 6,000 pairs. (Photo: D. Ristow)

Fig. 4: The picturesque ancient salt-pans on the island of Gozo, Malta. The number of salt-pans in the Mediterranean has been radically reduced during the last few decades. (Photo I. Škornik)

Fig. 5: Aerial shot of the abandoned part of the Sečovlje salt-pans called Fontanigge. In the middle of the shot is the Giassi channel, where the Museum of Salt-making is situated. (Photo: D. Podgornik)

Fig. 6: Common Kingfisher *(Alcedo atthis)* occurs in the area of the Sečovlje salt-pans almost all year round and is missing only in spring. At that time we can find it in the upper part of the Dragonja river, where it breeds in the characteristic holes made in the river banks. (Photo: T. Makovec)

Fig. 7: In the Eastern Adriatic, the Parrotfish *(Sparisoma cretense)* was recorded for the very first time as late as in the year 2000. The record of this species in the surroundings of Palagruža Island is yet another case of thermophilous species occurring in the Adriatic in the last few years. (Photo: B. Furlan)

Fig. 8: Azure Window on the island of Gozo (Malta) is an exceptional pearl of the intact Mediterranean nature. (Photo: I. Škornik)

NAVODILA AVTORJEM

1. *ANNALES: Anali za istrske in mediteranske študije - Annali di Studi istriani e mediterranei - Annals for Istran and Mediterranean Studies* (do 5. številke: *Anali Koprskega 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. Zaželjeno 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 inštitucije, kjer je zaposlen, oz. domači naslov vključno s poštno številko in morebitnim naslovom elektronske pošte.

Uredništvo razvršča prispevke v naslednje **kategorije:**

Izvirni znanstveni članki vsebujejo izvirne rezultate lastnih raziskav, ki še niso bili objavljeni. Dela pošlje uredništvo v recenzijo. Avtor se obvezuje, da prispevka ne bo objavil drugje.

Pregledni članki imajo značaj izvirnih del. To so natančni in kritični pregledi literature iz posameznih zanimivih strokovnih področij.

Predhodno sporočilo in *Gradiva* imajo ravno tako značaj izvirnih del.

Strokovni članki prikazujejo rezultate strokovnih raziskav. Tudi te prispevke uredništvo pošlje v recenzijo in avtor se obveže, da prispevka ne bo objavil drugje.

Poročila vsebujejo krajše znanstvene informacije o zaključenih raziskovanjih ali kratek opis strokovnih in znanstvenih knjig ali srečanj. Taki prispevki ne smejo presegati 5 strani.

Mladinske raziskovalne naloge morajo biti urejene kot strokovna dela.

Komentarji so namenjeni aktualnostim s strokovnega področja. Ne smejo presegati 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. Zaželjeni 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 Koprskega 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 with eventual E-mail address.

Articles are arranged in the following eight **categories:**

Original scientific papers 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.

Review articles bearing the character of original works. These are critical and detailed reviews of literature from various interesting fields of research.

Preliminary communication and Materials also bearing the character of original works.

Professional papers presenting results obtained through research. They too will be reviewed, and authors oblige themselves not to publish them elsewhere.

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 was 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 purpose 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 abbrevation of archive source is to be stated in brackets in the text of the article. The abbrevation 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. In: 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.

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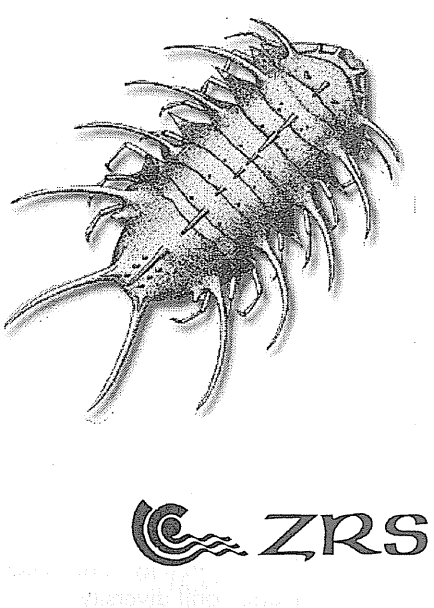
SUPLEMENT - ABSTRACTS

European Science Foundation Exploratory Workshops in the Life and Environmental Sciences

"Pattern and Process in Balkan Biodiversity"
"Vzorci in procesi v balkanski biodiverziteti"

September 25 - 28, 2001 : Koper, Slovenia



THE
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European Science Foundation Exploratory Workshop

The Life and Environmental Sciences "Patterns and Process in Balkan Biodiversity"

Fakulteta za humanistične študije/Faculty of humanities
Glagoljaška ul. 8, Koper, Slovenia

PROGRAM/PROGRAMME

Torek/Tuesday 25 September

19.00
Formal adresses (Kryštufek, Griffiths, Gábor, Darovec)
Pozdravni nagovori (Kryštufek, Griffiths, Gábor; Darovec)

Sreda/Wednesday, 26 September 26

Determinants of biodiversity: Chair – Dr. Huw Griffiths

9.00
Petru M. Bănărescu, Instututl de Biologie, Bucurest:
The pattern of distribution of the freshwater fauna of the Balkan Peninsula
Vzorec razširjenosti sladkovodne favne na Balkanu

9.45
Rachel Flecker, Department of Earth Sciences, University of Cambridge:
Evaluating marine connections between Paratethys and the Mediterranean in the Late Miocene
Ovrednotenje morskih povezav med Paratetisom in Sredozemljem v poznem miocenu

11.00
Nena Galanidou, Department of History & Archaeology, University of Crete:
The environmental impact of prehistoric human groups on the Balkan landscape
Okoljski vpliv prazgodovinskih človeških skupin na balkansko krajino

11.45
Boris Sket, Department of Biology, University of Ljubljana:
An alternative biogeographical regionalization of Slovenia (as a possible clue for surrounding countries)
Alternativna biogeografska regionalizacija Slovenije (kot možno vodilo za obdajajoče dežele)

Vegetation and climate: Chair – Dr. Mike Frogley

14.00
Warren J. Eastwood, School of Geography and Environmental Sciences, University of Birmingham:
Late quaternary climate change in the Eastern Mediterranean
Klimatske spremembe ob koncu kvartarja v vzhodnem Sredozemlju

14.45
David Watts, Department of Geography, University of Hull:
Biotic interactions and environmental change in the Balkans during the holocene
Biotske interakcije in okoljske spremembe na Balkanu v holocenu

16.00
Tone Wraber, Department of Biology, University of Ljubljana:
Dinaric floral diversity
Pestrost dinarske flore

16.45
P. Chronis Tzedakis, School of Geography, University of Leeds:
Response of glacial stage tree populations in Greece to orbital and suborbital climate variability
Odziv ledenodobnih drevesnih populacij v Grčiji na klimatske spremembe

Četrtek/Thursday, September 27

The Quaternary: Chair – Dr. Chronis Tzedakis

9.00
Michael R. Frogley and Richard C. Preece, Centre for Environmental Research, University of Sussex and Department of Zoology, University of Cambridge:
A faunistic review of the modern and fossil molluscan fauna from Lake Pamvotis, Ioannina, an ancient lake in NW Greece: implications for endemism in the Balkans
Favnistični pregled sodobnih in fosilnih mehkužcev iz jezera Pamvotis, starodavnega jezera v SZ Grčiji s poudarkom na balkanskem endemizmu

9.45
Huw I. Griffiths and Michael R. Frogley, Department of Geography, University of Hull and Centre for Environmental Research, University of Sussex:
Fossil ostracods and faunistics: what they tell us about the evolution of regional biodiversity
Fosilni dvoklopniki in favnistika: kaj nam povedo o evoluciji regionalne biotske raznovrstnosti

11.00
Gerhard Storch, Forschungsinstitute und Natur-Museum Senchenberg, Frankfurt a. Main
Pleistocen mammal dispersal
Razširjenost pleistocenskih sesalcev

11.45
Jane M. Reed, Department of Geography, University of Hull:
Diatoms as biodiversity indicators in lakes of the circum-Mediterranean
Diatomeje kot kazalci biotske raznovrstnosti v jezerih okrog Sredozemlja

Evolution: Chair – Dr. Boris Kryštufek

14.00
Jan Zima, Institute of Vertebrate Biology, Czech of the Academy of Sciences, Brno:
Small mammal biodiversity and cytogenetics
Biotska raznovrstnost malih sesalcev in citogenetika

14.45
Peter Trontelj, Rudi Verovnik and Boris Sket, Department of Biology, University of Ljubljana:
Cryptic speciation in Dinaric karst waters: molecular approaches reveal a new dimension of diversity
Kriptično nastajanje novih vrst v vodah dinarskega krasa: molekularni pristopi razkrivajo novo dimenzijo raznovrstnosti

16.00
Martina Podnar, Werner Mayer, Nikola Tvrtković and Eduard Kletečki, Croatian Natural History Museum, Zagreb, Croatia
Phylogeny and biogeography of Adriatic lizards –
a contribution to the Dinaric (Western Balkan) phylogeographic scenario
Filogenija in biogeografija jadranskih kuščaric –
prispevek k dinarskemu (zahodni Balkan) filogeoografskemu scenariju

16.45
Panos Economidis, Aristotle University, Thessaloniki, Greece
Speciation in Balkan loaches
Speciacija balkanskih smrkežev

Petek/Friday, September 28

9.00
Alexei V. Korniushin, International Solomon University, Kiev:
Bivalve molluscs fauna of ancient lakes in the context of historical biogeography in the Balkan region
Favna školjk v starodavnih jezerih v kontekstu historične biogeografije na Balkanu

9.45
Georg Džukić and Miloš L. Kalezić, Institute for Biological Research "Siniša Stanković",
Belgrade and Institute of Zoology, Belgrade:
Diversity of amphibians and reptiles on the Balkan Peninsula
Raznovrstnost dvoživk in plazilcev na Balkanskem polotoku

11.00
Christo Deltshev, Institute of Zoology of the Bulgarian Academy of Sciences, Sofia:
A zoogeographical review of the spiders (Araneae) of the Balkan Peninsula
Zoogeografski pregled pajkov (Araneae) na Balkanskem polotoku

11.45
Boris Kryštufek, Slovenian Museum of Natural History, Ljubljana:
Mammal biodiversity in the Balkans
Biodiverziteta balkanskih sesalcev

Zoogeography II: Chair – Prof. Boris Sket

14.00
Giorgos Catsadorakis, Society for the Protection of Prespa, Prespa:
The biogeography of Prespa: knowledge and ignorance
Biogeografija Prespanskega jezera: znanje in nevednost

14.45
Anton Brancelj and Tanja Pipan, National Institute of Biology, Ljubljana and Karst research Institute
ZRC SAZU, Postojna:
Micro and macroscale diversity of copepods in the subterranean realm of Slovenia
Mikro- in makrodiverziteta ceponožcev v podzemnem svetu Slovenije

15.30
Martina Podnar & Werner Mayer
Croatian Natural History Museum, Zagreb, Croatia
Intraspecific mtDNA variation in *Podarcis* lizards
Intraspecifična mtDNA variacija pri kuščaricah iz rodu Podarcis

16.15
Lovrenc Lipej and Jakov Dulčič, ZRS Koper, MBP-NIB Piran and Institute of Oceanography & Fisheries, Split:
Factors affecting the diversity of the Adriatic ichthyofauna
Dejavniki, ki vplivajo na raznovrstnost jadranske ribje favne

THE PATTERN OF DISTRIBUTION OF THE FRESHWATER FAUNA OF THE BALKAN PENINSULA

Petru M BĂNĂRESCU
Institute of Biology, Bucharest, Romania

Each river drainage in the Balkan Peninsula has its own faunistic pecularities. The Danube Basin's aquatic fauna has a marked central European character. Two of the ten endemic fishes of the basin are confined to its southern and south-western *(i.e.* its Balkanic) sector. Many genera of higher crustaceans and hydrobioid snails, especially hypogean taxa, are endemic to the south-western area of the Danube Basin, some of them are related to western Balkanic genera, however, the area also features a lot of endemic species belonging to western or Holo-balkanic genera.

Central European and Danubian fish and aquatic invertebrates are also present in the rivers of the northern Aegean watershed; there are differences between the eastern Aegean rivers (R. Maritza, R. Mesta, R. Struma) and the western ones (R. Vardar and others). In the eastern Aegean rivers are present widely distributed European species inhabiting standing or slowly running water, while in the western rivers live rheophilic species, shared only with the Danube or with a few other neighbouring rivers; none of them live either in the eastern Aegean drainages or in the western Balkanic ones.

The aquatic fauna of the western Balkan is the richest in Europe and includes a very high number of endemic genera and species. Most species have restricted distributions in the western Balkan area; the four Dalmatian riverine drainages and especially the lakes of Skadar and Ohrid each have their own endemics. The southern Balkans includes numerous endemics too, most having quite restricted ranges. Several genera and species are restricted to two or three of the five Balkan districts. These taxa can be designated as "Balkanic" in wide sense.

The efficiency of water divides as barriers differs amongst various groups. These provide very efficient barriers for fishes, crayfishes and large sized molluscs, and so explains the great differences between the fish faunas of the western Balkan and the Danube drainages. Water divides are, on the contrary, less efficient barriers for hypogean aquatic animals such as hydrobioid snails and aquatic insects - the genera and species of these groups, present in the south-western tributaries of the Danube, have marked west Balkanic ties.

The following historical biogeographical categories can be identified:

- those with central European or Palearctic ties: species more widely distributed and with different ages in the Peninsula. The central European species present in the Aegean rivers dispersed through the Black Sea when it was a brackish water body, whilst the Danubian rheophilic species dispersed by mean of river captures from the Danube's tributaries in the R. Vardar.
- those with Anatolian or western Asian affinities, *e.g.* the fish genus *Pseudophoxinus*, the subgenera *Luciobarbus* of *Barbus* and *Bicanestrinia* of *Cobitis*, and a speciose lineage of hydrobioid snails (raised by Radoman to family rank "Orientallinidae").
- members of lineages of marine Tethyan origin: species of the epigean snail genera *Theodoxus* and *Melanopsis* and a numerous hypogean species of atyd and peracarid crustaceans.
- offshoots of the Mediterranean marine fauna.

Key words: biogeography, Balkan, hydrology, river catchments, faunal provinces

EVALUATING MARINE CONNECTIONS BETWEEN PARATETHYS AND THE MEDITERRANEAN IN THE LATE MIOCENE

Rachel FLECKER
Department of Earth Sciences, University of Cambridge, UK

Fossil distribution patterns have long been used to establish the timing and nature of connectivity between marginal basins and the global oceans. However, since the salt flux can be independent of the water flux in semi-enclosed seas, faunal and lithological responses to salinity change may not be directly linked to changes in restriction. Recent developments in geochemistry provide additional tools for examining the relative influence of global marine and freshwater fluxes on marginal basins.

Sr isotope ratios of marginal basin water can be recorded and preserved both in the calcitic shells of subaqueous fauna and in some chemical lithologies. Late Miocene Mediterranean and Paratethean samples were selected from three contrasting environments:

- Hypersaline conditions indicated by evaporite (gypsum) deposits.
- An environment with normal marine salinity containing abundant foraminifera.
- A brackish water environment indicated by low salinity ostracods.

Sr isotope analyses for all three environments show similar deviation from coeval oceanic $^{87}Sr/^{86}Sr$ values. This suggests that they all had a comparable degree of oceanic influence, significantly less than the Mediterranean today. Hydrologic modelling of marginal systems indicates that the rate of restriction may be a more important control on salinity change than absolute degree.

Evaluating palaeo-rate of restriction in the Balkan region requires an understanding of eustatic and tectonic controls on sealevel change along with hydrologic modelling on a sub-basin scale. While there are a large number of potential errors (*e.g.* palaeoclimate and stratigraphic framework), this approach does represent a novel way of examining the causes and timing of changes in faunal distribution patterns.

Key words: Miocene, Paratethys, Mediterranean, geochemistry, Sr isotopes

THE ENVIRONMENTAL IMPACT OF PREHISTORIC HUMAN GROUPS ON THE BALKAN LANDSCAPE

Nina GALANIDOU
Department of History & Archaeology, University of Crete, Greece

The aim of this paper is to introduce the human factor, in the shape of our prehistoric past, into the study of Balkan biodiversity. This will be achieved by examining the overall effects on the environment of the movements, settlement patterns and subsistence and economic practices of the human groups who lived in this area between the Palaeolithic and the Bronze Age. The paper's perspective is a long-term one, for this period encompassed many thousands of years, witnessing the extinction of many animal and plant species and the rise of human groups with many different economies and ways of life. The most important questions that arise are whether these dramatic events were related to each other and what they can teach us for the future.

Careful consideration of the palaeoenvironmental and archaeological records suggests a dichotomy roughly dividing the Pleistocene and the early Holocene from the late Holocene. The end of the Pleistocene coincided with the extinction of some of the populations that throve during the Ice Age; human groups, however, had only a minimal impact on this process. It is not until the later periods of Balkan prehistory, the Neolithic and the Bronze Age, when new domesticated species were introduced, that the environmental impact of humans becomes clearly visible. To explain these processes requires a comparative examination of a number of factors such as demography, economic practices and subsistence patterns from the Palaeolithic onwards. At the same time it is interesting to explore epistemological issues such as time scale differences and the idealised views of a dichotomy dividing hunter/gatherers from farmers and pastoralists, or primitive societies from complex ones, that lie behind the ways in which we approach the past and the explanations we give for it. The paper will thus develop on two levels. The first is factual: data are presented and the evidence suggesting how prehistoric human groups affected Balkan biodiversity is discussed. The second is more theoretical, exploring the epistemological foundations of our explanations.

Key words: environmental impact, Palaeolithic, Bronze Age, settlement, palaeoeconomy

AN ALTERNATIVE BIOGEOGRAPHICAL REGIONALIZATION OF SLOVENIA (AS A POSSIBLE CLUE FOR SURROUNDING COUNTRIES)

Boris SKET
Department of Biology, University of Ljubljana, Slovenia

Most attempts at the biogeographical regionalisation of the World (as well as of Slovenia) have been conceived as unified systems either for the animal world (Hadži, 1930; Bole, 1981), that of plants (Horvat, 1954; Meusel *et al.*, 1965; Wraber, 1969), or of both together (Matvejev, 1961, 1991). However, these organisms have at their disposal very different means of expansion and dispersion. This is only to a low degree bound to their gross taxonomic affiliation (even in the sense of plants *vs.* animals) and mainly depends on their active or passive means of locomotion, ethology, competition fitness, habitat type and other niche characters, niche specialisation degree, *etc.* Taxa of different dispersal abilities have therefore often been either excluded from certain distribution schemes, or alternatively they caused a great complexity of them if their so-called ecological and historical biogeographies had to be combined. This paper is an attempt to partition a region within a realm (*e.g.* the Palaearctic) differently for different types of biota. Three biogeographic patterns have been recognised.

- Pattern 1: **the pattern of the territorially fixed** fauna and flora is mainly historically founded. These are mainly the biota of "cryptic" habitats like soil, hypogean habitats, and springs; however, some inhabitants of very exposed habitats belong here, like some lizards or mainly lithophilous plants. Slovenia could be divided in this context into a (1a) **Dinaric,** (1b) **south alpine,** and (1c) **prealpine-subpannonian regions.**
- Pattern 2: the **pattern of the territorially unbound** fauna and flora is mainly ecologically founded. It concerns organisms with great dispersion and competition abilities and either low niche specialisation or even the ability to influence local climates (*e.g.* tree species). A large portion of terrestrial animals and plants as well as animals of stagnant waters, most of the running water fauna, and nearly all the aquatic flora belongs here. Slovenia could be divided into a (2a) **high alpine,** (2b) **alpine-dinaric,** (2c) **prealpine-predinaric,** (2d) **prepannonian** and (2e) **submediterranean regions;** 2b and 2c being hardly distinguishable.
- Pattern 3: the **pattern of the stream fauna (and flora?)** is mainly influenced by recent hydrographic connections. It mostly concerns fish faunas and, to a much lesser degree, invertebrates. Slovenia could be divided into the (3a) **Danubian** and the (3b) **Adriatic regions,** while the (3c) inner karstic region without the surface outflow is only characterised by the lack of some species.

In the overlapping parts of the submediterranean region (of territorially unbound biota) with the dinaric region (of territorially bound biota), a particularly rich combination of the thermophile fauna/flora and the endemic relicts occurs. This is particularly perceivable further southeast in Slovenia.

Key words: biogeography, biotic classification, Slovenia, Balkans

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LATE QUATERNARY CLIMATE CHANGE IN THE EASTERN MEDITERRANEAN

Warren J. EASTWOOD
School of Geography and Environmental Sciences, University of Birmingham, UK

The Mediterranean is located in a sensitive climatic zone that straddles the subtropical high pressure belt and the Westerly circulation system. Recent studies have shown that during the late Pleistocene this area was highly susceptible to the global effects of changes in ocean and atmospheric circulation in the North Atlantic. The record of climate change obtained from isotopic studies from the Greenland ice cap highlight the marked swings in climate for regions bordering the North Atlantic during the late Pleistocene but suggest that the overall climate for the Holocene period has been uniquely stable, with the exception of a marked event at 8,200 cal. yr BP. However, individual records from a variety of sources (pollen, diatom, lake level, mollusc, ostracod, stable isotope) have the potential to provide regional patterns of climate variability. This paper reviews and synthesises our understanding of late Pleistocene and Holocene changes in climate and assesses the importance of these data to the prediction of future climate changes and issues surrounding natural resource management and biodiversity.

Key words: climate change, Pleistocene, eastern Mediterranean, palaeolimnology, pollen

BIOTIC INTERACTIONS AND ENVIRONMENTAL CHANGE IN THE BALKANS DURING THE HOLOCENE

David WATTS

Department of Geography, University of Hull, UK

As one of the main peninsular refuge areas of Europe during the Pleistocene (the others being Italy and Iberia), the Balkans are of particular interest to biogeographers and others who seek to understand the processes of biotic change as the area responded to environmental warming during the Holocene.

With a complex geology and relief, and a variable pattern of climate, the viscitudes of which are by now fairly well known, both at present and during the post-Pleistocene past, vegetation responses are particularly interesting, involving as they did a mixture of essentially northern, Mediterranean and continental species at the beginning of the Holocene. The presence of glacial microrefuges at this time appears to have greatly facilitated the spread of forests, but good scrubland was also identifiable.

The spread of forests was complicated by the fact that some species changed their distribution only slightly, eventually becoming endemic or extinct: others had a massive extension of range. Reasons for this will be examined. In addition, molecular changes in some species, along with significant differences in the altitudinal ranges of others, will be noted. The particular dominance of certain species *(e.g. Pinus)* in the western half of the area is explained, along with regional and local changes of vegetation elsewhere.

An understanding of these will be helpful to any explanation of animal distributions in the Balkans, and to the human-induced modifications of both, which followed.

Key words: environmental change, Holocene, climate, *Pinus,* vegetation

RESPONSE OF GLACIAL STAGE TREE POPULATIONS IN GREECE TO ORBITAL AND SUBORBITAL CLIMATE VARIABILITY

P. Chronis TZEDAKIS
School of Geography, University of Leeds, UK

Quaternary palaeoclimate research has provided information across the entire spectrum of temporal scales from orbital to interannual changes, using archives ranging from ice cores to corals. However, the bulk of the information available is concentrated on variations occurring on orbital and, more recently, suborbital/millennial frequencies, mainly because of limitations on the resolution of the most prevalent types of records. As a result of intensified research activities over the last decade, there has been a substantial increase in our understanding of the character of climate variability, with new palaeoclimate records (mainly marine and ice cores), extending over multiple glacial-interglacial cycles and yet able to resolve millennial- (or even finer) scale events. Such sequences provide the environmental backdrop against which the response of vegetation, as deduced mainly from the fossil pollen record, can be assessed. However, establishing the nature and extent of vegetation changes relative to the external forcing is hindered by the scarcity of suitable terrestrial sequences, extending beyond the Holocene. Intermittent deposition and erosional activity in continental sedimentary environments, means that the terrestrial record is in its vast majority extremely fragmented. Long, continuous, pollen-bearing sedimentary lake sequences are found only in exceptional circumstances and a handful of these occur in Greece. There are now enough long pollen sequences studied in Greece to provide an insight into the vegetation response both on long glacial-interglacial timescales, but also on millennial frequencies. In addition, they also afford a first glimpse into the spatial differentiation of the response. Given the prominent position of the Balkans as a refugial area, particular attention is paid here to the nature of temperate tree populations during glacial periods.

First, an attempt is made to examine the long-term persistence and spatial distribution of residual tree populations in Greece. It has long been suggested that refugial populations would be primarily concentrated in areas proximal to moisture sources (*e.g.* Ionian Sea) and of high topographic variability. The palaeoecological record provides support for this idea with northwest Greece showing consistently higher levels of representation of temperate tree pollen through multiple glacial intervals than areas to the east or south. Second, the impact of millennial-scale oscillations on glacial stage tree populations is considered. What emerges is that changes in the coupled air-ocean system of the North Atlantic had a downstream impact on the size of tree populations in areas as far east as Greece, most critically through changes in moisture availability. However, while all pollen sequences provide evidence of the impact of such changes on glacial tree populations, they also show a distinct geographical differentiation of the response in terms of the amplitude of changes. In some areas, high-amplitude increases in tree populations followed by collapses are recorded. Of interest are interstadial population increases of certain taxa in locations which are not considered prime refugial areas, suggesting recolonization from beyond the immediate catchment. In other areas, tree populations persist at intermediate levels, with climate oscillations having a relatively subdued impact. These results underline the importance of local conditions in modulating the response of vegetation. They also raise questions on the degree of range expansion and contraction during such climatic oscillations and, by extension, the extent of gene flow between refugial populations. Ultimately, they provide an opportunity to formulate more concrete hypotheses that may be tested by genetic data.

Key words: climate variability, orbital forcing, trees, refugia, lake sediments

A FAUNISTIC REVIEW OF THE MODERN AND FOSSIL MOLLUSCAN FAUNA FROM LAKE PAMVOTIS, IOANNINA, AN ANCIENT LAKE IN NW GREECE: IMPLICATIONS FOR ENDEMISM IN THE BALKANS

Michael R. FROGLEY
Centre for Environmental Research, University of Sussex, UK

Richard C. PREECE
Department of Zoology, University of Cambridge, UK

The Balkans are justifiably famous for their unusually rich biodiversity. Isolated ancient lakes such as Ohrid and Prespa have developed remarkable endemic faunas, attesting to the complex biogeographical evolution of the region. Despite the detailed biological investigation of such sites, however, many key localities in the Balkans remain poorly known, particularly with regard to their fossil histories. Here we present an account of the aquatic molluscan fauna from Lake Pamvotis, an ancient lake located within the Ioannina Basin of NW Greece, that has a fossil record stretching back to the Plio-Pleistocene. Unlike the faunas from Ohrid and Prespa, however, the modern molluscan fauna of Lake Pamvotis does not exhibit spectacular endemism, as only four of the thirty-seven species that now occur in the lake and its surrounding marshland and springs appear to be endemic. Eight of these extant species have been found in Holocene sediments and four have records extending back beyond 200 kyr, but these are borehole records, so the faunas are certain to have been more diverse in the past. It is significant that older, magnetically reversed sediments from Ioannina have yielded additional taxa, including forms of *Viviparus* that appear to show differences in shell ornamentation with time. By comparing the Ioannina record with other extant and fossil lake sequences from the region, we consider what implications this might have in terms of the evolution of both Lake Pamvotis and other Balkan sites.

Key words: Quarternary, Molluscs, Lake Pamvotis, Greece, palaeoecology

FOSSIL OSTRACODS AND FAUNISTICS: WHAT THEY TELL US ABOUT THE EVOLUTION OF REGIONAL BIODIVERSITY

Huw I. GRIFFITHS
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Although still under-researched, the ostracod fauna of the Balkans is well-known for its large numbers of endemic species, many of which occupy localised distributions in the karst or in biodiversity 'sump' areas such as Lake Ohrid. Moreover, very diverse PlioPleistocene faunas have been described - particularly by workers from the former FSR Yugoslavia. We review these two datasets, and incorporate further information derived from recent fine-scale studies of extended (> one climatic cycle) lake sediment records from Pamvotis (W. Greece) and Kopais (E. Greece). These analyses provide additional insights into the temporal structuring of aquatic biodiversity and the timing of colonisation events. Contrasts are also made with faunistic and palaeoecolgical datasets from adjacent regions - notably western Anatolia.

Key words: Ostracoda, Quarternary, recent, palaeobiogeography, southern Balkans

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DIATOMS AS BIODIVERSITY INDICATORS IN LAKES OF THE CIRCUM-MEDITERRANEAN

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Diatoms (single-celled siliceous algae) occur in virtually all water bodies, are abundant, diverse and sensitive to a wide range of water chemistry variables. In lake sediment studies of past environmental change, their power as highly sensitive monitors of temporal trends in environmental variables such as salinity (related to lake-level and climate change) or nutrient status is widely acknowledged. Over the past decade diatom research has advanced considerably, with the development of transfer functions based on large modern regional data-sets of water chemistry and diatom assemblage composition data, from which to quantify past changes in water chemistry variables.

The Mediterranean regions of the Balkans, Turkey and Spain contain a wide variety of wetlands, including fresh (hydrologically open) and saline (hydrologically closed) lakes. Many of these wetlands are threatened increasingly by the effects of human-induced eutrophication and accelerated water abstraction, such that issues surrounding conservation and biodiversity are of particular concern. Whilst existing diatom-based research has been aimed primarily at reconstructing past environmental change, the recent expansion of diatom study in these regions has produced for the first time large regional data-sets of modern ecological data and an increasingly large body of long (last c. 10-20,000 yr.) and short (last c. 150 yr.) term palaeolimnological data, from which to assess temporal trends in biodiversity, both on a site-specific and regional basis.

This paper explores the potential of diatoms as indicators of biodiversity in the circum-Mediterranean, based on modern ecological and palaeoecological studies of lakes of the Balkans, Turkey and Spain, and by comparison with previously published species inventories for particular lakes. The influence of taxonomic nomenclature, habitat variation and sampling site on apparent biodiversity is discussed, and temporal trends are assessed using simple biodiversity indices. It is suggested that one of the most valuable outcomes of using the long-term palaeolimnological record to assess biodiversity, by reference to large modern ecological data-sets, is that one may identify clearly the past existence of characteristic diatom assemblages (and by inference, lacustrine environments) which now have no modern analogue in the regional flora.

Key words: diatoms, Mediterranean, palaeolimnology, biodiversity, transfer functions

CRYPTIC SPECIATION IN DINARIC KARST WATERS: MOLECULAR APPROACHES REVEAL A NEW DIMENSION OF DIVERSITY

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The aquatic fauna of the Dinaric karst area of the western Balkan Peninsula is renowned for its endemism and high diversity. This species richness is chiefly due to a high number of specialists inhabiting different types of subterranean waters, karst springs, resurgences, sinking rivers and other types of karst waters. Particularly rich groups with many endemic species can be found among crustaceans (*e.g.* amphipods, isopods, copepods), gastropods (*e.g.* Hydrobioidea), leeches (Erpobdellidae) and fishes (Cyprinidae). Many of these taxa live only in small, restricted areas, especially the subterranean or stygobitic species. The Dinaric region is known to hold the richest stygobitic fauna in the world. However, little is known about the processes and historical events that shaped such a rich fauna.

In contrast to many highly endemic, restricted-range-species, there are a number of widely distributed species occupying the same habitats. They are often morphologically homogeneous across their entire range. Examples of such taxa are the blind cave salamander *Proteus anguinus,* the cave shrimp *Troglocaris "anophthalmus",* the tube worm *Marifugia cavatica* and the leech *Dina lineata.* It has already been suggested that each of them might in fact represent a diverse species aggregate. The genetic patterns of their diversification might provide clues to the speciation process in karst waters.

Initial molecular genetic studies were conducted on *Dina lineata, Asellus aquaticus* and *Proteus anguinus.* Nuclear ribosomal ITS sequences, mitochondrial ribosomal genes and RAPDs have been employed as molecular markers. One of the most striking results of these studies was the high degree of isolation between neighboring populations. Adjacent populations of *D. lineata* differed from one another in their ITS2 sequences even more than some closely related erpobdellid species from each other. No gene flow could be detected between them. The most probable factor causing this isolation is the specific hydrography of karst waters. During the karstification process, rivers and other water bodies became fragmented in an island-like manner. The original dispersion must have taken place prior to extensive karstification, when the dispersion pathways were still present. The cryptic speciation of *D. lineata* can thus be explained by a series of vicariant events. A similar scenario may hold for most of the widely distributed genera with many endemic species and subspecies.

The case of troglomorphic forms of *Asellus aquaticus* demonstrates that the speciation processes can be more complex when it is linked to the invasion of caves. RAPD data have revealed that the stygobitic *A. a. cavernicolus* from Planina Cave does not interbreed with surface populations, with which they have potential physical contact. A second stygobitic population in the subterranean R. Reka some 30-km away clearly arose from an independent cave invasion. Moreover, a third, only partially troglomorphic population is known from the Postojna-Planina cave system. It arose from a more recent invasion and does not interbreed with the fully troglomorphic populations in the same system. The temporal, not the spatial component of isolation played the main role in producing this unique case of sympatric occurrence of two independent troglobitic descendants of the same surface species.

One can conclude that molecular genetic data have confirmed some predictions about the diversity patterns of aquatic animals of the Dinaric karst, like (1) the existence of cryptic species and (2) multiple independent steps of a single ancestral species towards a subterranean lifestile. They further provided evidence that vicariant habitat fragmentation events played a major role in the formation of species richness.

Key words: speciation, hypogean fauna, *Proteus, Asellus,* molecular biology

PHYLOGENY AND BIOGEOGRAPHY OF ADRIATIC LIZARDS - A CONTRIBUTION TO THE DINARIC (WESTERN BALKAN) PHYLOGEOGRAPHIC SCENARIO

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The flora and fauna of the Adriatic coast and especially its islands is under a strong antropogenic influence that caused extremely large Holocene changes in its composition. Thus, all data that still can be obtained from natural population remnants are of major importance. Together with the fossil and sub-fossil records, they can be used to reconstruct the history of colonisation of the Dinaric region. The distribution of endemic subspecies, and some congruent patterns of intraspecific variability imply the existence of the two main centres of diversity for the mainland species: one located at the region of Kvarner and a second in Dalmatia. These regions probably were also two distinct glacial refugia. The fact that today as many as 12 lacertid species inhabit the east Adriatic coast opens the possibility, through a phylogeographic approach, for a significant contribution to the general knowledge about the history of colonisation of this area.

Preliminary results of investigations of Adriatic populations of Podarcis sicula *and* P. melisellensis *based on the analysis of mitochondrial (mtDNA) markers will be presented. The contribution of these data to the elucidation of the colonisation pathways during and after the Pleistocene will be discussed. Some old, already forgotten records, as well as some new ones will be highlighted.*

Key words: speciation, islands, phylogeny, lizards, Lacertidae

BIVALVE MOLLUSCS FAUNA OF ANCIENT LAKES IN THE CONTEXT OF HISTORICAL BIOGEOGRAPHY IN THE BALKAN REGION

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Ancient lakes with their unique plant and animal communities are well known as "hot spots" of biodiversity and refuges for relict faunas. Therefore, investigations of these peculiar habitats are important for biogeographical regionalisation, the reconstruction of faunal history and understanding the mechanisms of speciation (Stanković, 1960). Among animal groups, gastropod molluscs are distinguished by the great diversity of endemics in some ancient lakes (Baikal, Tanganyika and Ohrid) and the presence of high rank endemic taxa (families/subfamilies in the first two lakes, genera/subgenera in the latter). Bivalve mollusc taxa seem to be more conservative and widespread, but nevertheless family Sphaeriidae is represented by endemic species and subspecies in Baikal, Ohrid, Prespa, Biwa, the African Great Lakes and Titicaca (see Korniushin *et al.* (2000) for a review), and a number of endemic *Corbicula* species are known from the ancient lakes of Sulawesi, Indonesia. All endemic lacustrine bivalves belong to widely distributed genera, except the unique cemented bivalve from Lake Poso included in a separate genus (family Corbiculidae).

At present, twelve species of bivalves are known from Lake Ohrid and five from Lake Prespa (Dhora & Welter-Schultes, 1996; Korniushin, *unpubl.).* Most of them have broad Palaearctic or European ranges, the recent distribution of *Microcondylaea compressa* (Menke, 1830) is basically Mediterranean. Two endemic species *(Pisidium edlaueri* Kuiper, 1960 from Ohrid and *P. maasseni* Kuiper, 1987 from Prespa) proved to be close relatives of the Holarctic *P. nitidum* Jenyns, 1832 (Korniushin *et al.,* 1998). *Pisidium subtruncatum* Malm, 1855 is represented in Ohrid by an endemic subspecies. Noteworthy, such species as *P. amnicum* (Müller, 1774), *P. henslowanum* (Sheppard, 1823), *P. moitessierianum* Paladilhe, 1866 (all found in Ohrid), as well as *P. nitidum* Jenyns, 1832 are now represented in the Balkans by scarce, isolated populations.

Composition of the bivalve mollusc fauna in Ohrid and Prespa does not contradict the biogeographical concept of Stanković (1960) which suggests the origin of the lake's fauna from the freshwater fauna distributed across Eurasia in Tertiary. However, the group *P. (Odhneripisidium)* apparently having its roots in this ancient fauna is represented in Ohrid by only one species - *P. tenuilineatum* Stelfox, 1918, sporadically distributed in other European countries, while *P. annandalei* sensu Kuiper, 1962 (= *P. sogdianum* Izzatullaev & Starobogatov, 1986) is restricted in the Balkans to Greece.

The taxonomy of *Dreissena* in the Balkan region is rather intricate. In particular, the Ohrid form was once described as a new species and even included in a separate subgenus (Lvova & Starobogatov, 1982), but modern reviewers treat it as a variety of *D. polymorpha* (Pallas, 1771) (Dhora & Welter-Schultes, 1996). While Ponto-Caspian origin of *Dreissena* is evident, the exact sources for its invasion in the Balkan region need to be clarified by the further morphological and molecular studies.

Our study shows no testable relationship between the bivalve faunas of Ohrid and Prespa. Similarity between *P. subtruncatum recalvum* Kuiper, 1960 from Ohrid and the form of the same species living in Prespa (Korniushin *et al.,* 2000) can be explained by convergence, since similar characters (high triangular shell and broad hinge plate) develop independently in many lacustrine taxa.

Thus, the Balkan lakes are rather peculiar in respect of their bivalves, even if compare them to the older lakes with the higher general level of endemism, like Baikal and Tanganyika. However, biogeographic information provided by these molluscs is limited because of their low diversity and wide distribution. Revision of the extremely diverse Ohrid gastropods (71 species) by using exact methods of phylogenetic reconstruction including molecular phylogenetics seems to have great potential in this respect.

Key words: Mollusca, bivalves, ancient lakes, speciation, Ohrid, Prespa

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DIVERSITY OF AMPHIBIANS AND REPTILES ON THE BALKAN PENINSULA

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The Balkan amphibians and reptiles are diversified in many respects. First of all, there is an enormous species-richness in the Balkan Peninsula. Approximately 100 species of these vertebrates live in this part of Europe, with also the realistic possibility of the existence of a number of morphologically cryptic taxa.

Secondly, batrachofauna (amphibians) and herpetofauna (reptiles) of this part of Europe has diverse biogeographical origins and connections with other regions. Namely, the Balkans appear to have been centre of intensive speciation within some taxa. There is evidence that new species emerged during Tertiary (mostly Miocene and Pliocene), whilst subspecies origin was confined to the Pleistocene. Furthermore, there were intense migrations of amphibians and reptiles from other zoogeographical areas via two main migration routes (the Pontic Bridge and mostly the Morava River Corridor). In the first place, there is a large front of contact with steppes to the east and northeast, whilst the Aegean Islands constituted a connection with the African and Asian fauna. In addition, in contrast to the Iberian and Apennine peninsulas, the Balkan Peninsula is not separated by a mountain barrier from the European mainland, and thus is widely connected with central Europe and therefore, the rest of continent. This has crucial importance for the European batracho- and herpetofauna, because it has been shown that central and northern Europe were populated by expansions from a Balkan refugium in the Holocene. Also, some groups have withdrawn from northern and mid European latitudes, some of them now being restricted to southern refugial areas.

On zoogeographical grounds, the Balkan Peninsula is also characterised by numerous discontinuities; *i.e.* the zoogeographical map is very complex with elaborate subdivisions, as well as with a wealth of preglacial faunal elements. Also, this area is the strongest centre of reptile and amphibian endemnicity in Europe, with the more than 45 endemic species, and many relict taxa. Due to these facts, some parts of the Balkans, in particular the Adriatic triangle (broadly speaking Prokletije Mt. area), are recognised as being one of Europe's main biogenetic reserves. As these isolated populations are mostly at species' range limits, there are numerous cases of range shrinking in the Balkan area. Of all species living in Balkans, 53% have range limits there. Although most of these peripheral populations are not going to evolve into distinct entities, there is still an astonishing potential for further evolutionary diversification.

In terms of general biological phenomena, Balkan amphibians and reptiles usually have much more inter- and intrapopulation genetic variability (in terms of allelic variation and a number of distinct genomes) when compared with other European areas. Diverse types of hybridisation and intergradation zones, which are differently spatially orientated (N-S, NW-SE directions, vertical distribution), are common on the Balkan Peninsula. Interspecific and intraspecific heterochronic phenomena expressed as a retention of ancestral larval features by a reproductively mature adult descendent (paedomorphosis and paedogenesis, respectively) are common among Balkan tailed amphibians. Paedomorphosis characterises the only European real cryptobiont *(Proteus anguinus),* while the existence of alternative life-history pathways among individuals of the same population (paedogenesis) is extremely high in Balkan newts *(Triturus),* especially along the Dinaric Alps. Also, it seems that hybridogenesis occurs in a number of green frog complexes *(Rana* kleptons), more than elsewhere. Finally, as in other places in Europe, there are more reproductive modes (oviparity *vs.* viviparity) within a single species *(Lacerta vivipara).*

In general, genesis of the present day diversities of the Balkan amphibians and reptiles was influenced by numerous factors, e.g. habitat heterogeneity, topographic diversity (mostly influenced by Pleistocene glaciations), great variation in climate, differences in rates of immigration, evolutionary and ecological time, *etc.* It should be stressed that geological history and palaeogeography of the Balkan Peninsula has undergone complex perturbations, especially during the Tertiary. Also, there is a correspondence of zoogeographical boundaries with the distribution of deep lithospheric breakages (crustal megablocks), so that these geological events might profoundly effect the evolutionary history at least of some Balkan amphibians *(e.g. Triturus cristatus* superspecies).

However, for a more comprehensive picture of Balkan amphibians and reptiles we still lack many relevant data on longstanding taxonomic problems, population structure, distributional characteristics of some taxa (size, shape, boundaries, overlaps and locations of geographic ranges), especially those which can be considered as a "zoogeographic paradoxes" (occurrence of isolated populations in "unexpected places"). Also, historical biogeographical patterns remains almost unexplored thus far, including the phylogenetic relationships of species and, especially, taxon-area cladograms.

Key words: reptiles, amphibians, evolution, diversity, tectonics

A ZOOGEOGRAPHICAL REVIEW OF THE SPIDERS (ARANEAE) OF THE BALKAN PENINSULA

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According to their current distribution, the over 1,400 established spider species can be classified into 24 zoogeographical categories, grouped into 4 complexes (widely distributed, European, Balkan endemic and Mediterranean). The largest number of species belongs to the widely distributed complex, but the most characteristic are the Balkan endemics. The established number (389) in the latter category is high and reflects the local character of the fauna. In the context of palaeoenviromental changes since Pliocene, this phenomenon can be attributed to the relative isolation of the mountains compared to the lowlands. Moreover, the high percentage representation of endemics suggests an important process of autochthonous speciation. Thus, the Balkan Peninsula can be considered as being a major centre of speciation for the European araneofauna.

Key words: spiders, diversity, endemicity, Bulgaria, speciation

MAMMAL BIODIVERSITY IN THE BALKANS

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Mediterranean Europe is known to be a host of endemic taxa in general and in rodents in particular. In comparision with the remaining peninsulas (the Iberian and the Italian), the Balkans are particularly rich in both phylogenetic and biogeographic relics. It has been shown that the hot spots of European rodent diversity are focused in the Balkan Peninsula (including the Carpathian Basin) and adjacent parts of southern Ukraine and Ciscaucasia, where >80% of rodent genera and species occur on merely 11.4% of the continent's surface (Kryštufek & Griffiths, *in press*). Among the eight mainland European rodents with particularly restricted distributional ranges (range encompassing <1% of the continent's surface), no less than five are from the Balkans *(Mesocricetus newtoni, Dinaromys bogdanovi, Microtus felteni, M. tatricus, Miomymus roachi),* and a number of other species have similarly narrow ranges *(e.g. Spermophilus citellus, Nannospalax arenarius, Microtus thomasi, Apodemus mystacinus s. s.)*. Due to high chromosomal polymorphism in some taxa on one hand (particularly *Nannospalax leucodon*, but also *Sorex araneus* and *Microtus thomasi*) and a lack of comprehensive taxonomic treatments on the other, the number of taxa with very restricted ranges is likely to be higher than actually recognised. In addition, the island of Crete hosts two island endemics *(Crocidura zimmermani, Acomys nesiotes)* out of the three documented for Europe. This accords with the-oft suggested role of the Balkans as a Quaternary refugium - based on its age as a distinct landscape unit and also because of complex Plio-Pleistocene vicariant interactions between the Balkans and Anatolia. In general, mammalian spatial patterns have been poorly documented and studied - *e.g.* Mediterranean small mammal communities are less species rich than are continental ones, and the transition between the two lies at *c.* 700-900 m on the Dinaric Alps (north-western Balkans; Kryštufek & Griffiths, 1999). Mustelids show a monotonous latitudinal decline in α-diversity, with their highest values in the Carpathian Basin (Kryštufek, 2000).

Key words: mammals, refugia, biodiversity, authochthony

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THE BIOGEOGRAPHY OF PRESPA: KNOWLEDGE AND IGNORANCE

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In this paper I use biogeographic statistics referring to plants and several animal orders found in the Greek part of the Prespa area, and compare these with data from other well-studied areas in Greece and neighbouring Balkan countries. Data used concern vascular plants, monogenean fish parasites (platyhelminths), land snails, orthopteran insects, freshwater fishes, reptiles and birds, with the overall objectives of clarifing unclear issues, and highlighting up critical questions and gaps in our fundamental knowledge of the biogeographic particularities of this valuable area, that is characteristic of the central Balkans. In addition to the above data I also use data concerning distribution ranges of specific plant and animal species, geological and archaeological data and breeding performance parameters of certain bird species.

Drawing very concrete biogeographic conclusions in such an area at the transitional zone between Continental Europe and Mediterranean is as difficult as it is interesting. Although the area is most probably one of the best studied in the Balkans, the amount of available scientific data is still poor in comparison to many places in north and central Europe.

Key words: biodiversity, conservation, Prespa, Greece

MICRO AND MACROSCALE DIVERSITY OF COPEPODS IN THE SUBTERRANEAN REALM OF SLOVENIA

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Copepoda (Crustacea) are one of the most widely distributed groups of organisms in the World, ranging from free-living zooplankters to ecto- and endoparasites of a wide variety of aquatic organisms. Copepods inhabit high-mountain waters and deep-sea floor. All over the world subterranean environments are inhabited by numerous copepod taxa, and many of these are endemics. One of the richest areas for endemic subterranean copepods is the Dinaric area of SE Europe. In Slovenia (as the most north-westerly part of the Dinaric region) about 110 copepod taxa have been recorded, about half of which are stygobionts. At the moment there are about 20 endemics known - all but one are stygobionts belonging to the group Harpacticoida.

In recent years, intensive research on Slovenia's cave-dwelling copepods in caves has revealed a high number of taxa inhabiting percolating waters and adjacent pools. In these environments at least nine species new to science have been recognised. In total, 38 taxa were collected in seven horizontal caves (length = 75 m – 1 km). Of these, ten taxa could be designated as ubiquitous as they are found frequently in the subterranean environment, but after transport from epigean habitats, however, the rest are stygobitic and fourteen are endemics to Slovenia. This results in high density of endemics in an area of about 2,400 km^2, *i.e.* 1 taxon/170 km^2.

Between 11-17 different copepod taxa found per cave, regardless of its length (the 75 m cave featured 12 taxa, whilst 13 and 17 taxa were recorded from two caves > 1 km). Of 38 taxa only one *(Speocyclops infernus)* was found in all seven caves, whilst two more (genus *Parastenocaris*) were present in six caves. Fourteen taxa were found only at one location and seven of them were ubiquitous taxa, transported into the caves by accident; the rest were stygobitic taxa.

The high total number of taxa found in the caves, the high numbers of taxa per cave (11-17) with a dominance of stygobitic taxa, and the very low number of taxa common to all caves, indicate that biodiversity in subterranean environment is very high at both local and wider scales. This also suggests that some species still remain to be discovered in this environment.

Key words: cladocera, hypogean, endemicity, species richness, Slovenia

FACTORS AFFECTING THE DIVERSITY OF THE ADRIATIC ICHTHYOFAUNA

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The Adriatic comprises an independent biogeographical and ecological subunit of the Mediterranean owing to peculiarities evident from the composition properties of its life communities (biocenosis). During the past ten years several papers have been published on the occurrence of new fish species in Adriatic waters, bringing the number of fish species in the Adriatic Sea to 417 in 119 families *(i.e.* 72% of the species and subspecies known in the Mediterranean). The new records are mostly of thermophilic species. The movement of these species is also cited as evidence for the warming of Mediterranean waters. The greatest part of the south Adriatic basin has not been sufficiently explored as regards its ichthyofauna, particularly not at depths of >500 m.

Most species and subspecies of Adriatic fish, apart from some endemic species (6) and subspecies, belong to the Mediterranean and Mediterranean-Atlantic biogeographic region. During the last decades the number of thermophilic species in the Adriatic increased, mainly due to the effects of oceanographic changes. Some Lessepsian migrants were also reported in the Adriatic in recent years. On the other hand some native and even endemic species became endangered due to certain anthropogenic factors, notably uncontrolled fishing, eutrophication and different kinds of pollution.

Key words: fish, Adriatic, diversity, origins, conservation

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