CONTRIBUTION TO THE KNOWLEDGE OF THE CHTHAMALIDS (CRUSTACEA, CIRRIPEDIA) ON THE SLOVENE ROCKY SHORE (GULF OF TRIESTE, NORTH ADRIATIC SEA)

PRISPEVEK K POZNAVANJU VITIČNJAKOV (CRUSTACEA, CIRRIPEDIA) NA KAMNITEM SLOVENSKEM OBREŽJU (TRŽAŠKI ZALIV, SEVERNO JADRANSKO MORJE)

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Key words: *Chthamalus depressus* (*Euraphia depressa*), *Chthamalus montagui*, *Chthamalus stellatus*, vertical distribution, Slovene coast, North Adriatic Sea
Ključne besede: *Chthamalus depressus* (*Euraphia depressa*), *Chthamalus montagui*, *Chthamalus stellatus*, vertikalna razširjenost, slovensko morsko obrežje, severno Jadransko morje

ABSTRACT

In the supralittoral and mediolittoral of the Slovene coast, three species of chthamalids were recorded. The article discusses the species occurrence, vertical distribution patterns on two different substrata (sandstone and limestone) and presents a table for identification of recorded species.

IZVLEČEK

V supralitoralu in mediolitoralu slovenskega obrežja so bile zabeležene tri vrste vitičnjakov. Članek obravnava pojavljanje vrst ter vzorce vertikalne razširjenosti na dveh različnih podlagah (peščenjaku in apnencu) ter podaja tabelo za identifikacijo zabeleženih vrst.

1. INTRODUCTION

The Adriatic Sea is a long semi-enclosed basin of the Mediterranean Sea, whose northern part (North Adriatic) terminates in a relatively flat shelf with a mean depth of about 50 m. The Gulf of Trieste is a shallow marginal sea and the northernmost part of the Adriatic Sea surrounded by land on three sides. It contains relatively little water (only 0.4% of the Adriatic basin). It is characterized by high variations of salinity (32 to 38 PSU) and temperature (6,5°C in winter and 28°C in summer) and by high freshwater input mainly from the Soča (It. Isonzo), Tilment (It. Tagliamento), Rižana and Dragonja (Bussani et al. 2003) rivers. The tidal range is approximately 90 cm (Agencija RS za okolje 2009), while in the rest of the Mediterranean area the mean tidal amplitude is about 20-30 cm. The gulf is influenced mainly by the "burja" wind, blowing from the north-east to north-north-east, and "jugo", blowing from the south-south-east (Malačič et Jeromel 2005). The entire coast is also subject to intensive anthropogenic activity. All this make the gulf extremely sensitive to ecological changes.

The rocky substratum of the northern coast of the Gulf of Trieste consists mainly of limestone, while the southern part is composed of flysch layers with soft marl and solid sandstone (Pavlovec 1985, Ogorelec et al. 1997). The Slovenian coast, situated in the eastern part of the Gulf of Trieste, is characterized mainly by two rock types: flysch and limestone. This provides a useful area to test the role that the substrate plays in determination of community composition, distribution and density.

Recent studies reported that the main constituents among different species of the *Chthamalus* barnacles from the supralittoral and mediolittoral of the northern Adriatic rocky shores are: *Chthamalus depressus* (*Euraphia depressa*) (Poli), *C. stellatus* (Poli) and *C. montagui* Southward (Relini 1981, Zavodnik 1998, Zavodnik et al. 2005). The position and extension of chthamalids belts on the shore are generally related to tidal range and grade of exposure of the coast (Pannacciulli et Relini 2000).

Along the Slovene coast, only *C. depressus* for the supralittoral and *C. stellatus* for the mediolittoral zones are mentioned (Lipej et al. 2004). The first occurrence of the species *C. montagui* on the Slovene rocky shore was reported by Battelli et Dolenc-Orbanić (2008).

The purpose of this study was: a) to investigate the species composition and the distribution (at different tidal levels of the supralittoral and the mediolittoral zones) of the chthamalid communities on two different types of substrate (sandstone and limestone) and b) to give a general description of the identified species of chthamalids based on the external morphological features.

2. MATERIALS AND METHODS

Sampling was carried out in spring 2008 at three locations along the Slovene coast: Koper Bay – Ankaran (Lo1), Izola Bay – along the Koper-Izola coast (Lo2) and Piran Bay - Seča (Lo3) (Figure 1). The location Lo1 (Ankaran: 45° 34′ 17″ N, 13° 44′ 32″ E) was located on the northern side of Koper Bay, generally exposed to wave action generated by southwesterly and southeasterly winds. The location Lo2 (Koper-Izola coast: 45° 32′ 49″ N, 13° 41′ 11″ E) was situated on the southern part of Koper Bay. The shore was exposed to wave action and winds blowing from the north, west and northeast. The location Lo3 (Seča: 45° 30′ 01″ N, 13° 35′ 15″ E) was placed along the coast of Piran (Seča) Bay and exposed to wave action and winds blowing mainly from the west.

Although the mediolittoral zone of the Mediterranean rocky shore is usually divided into two parts (the upper mediolittoral, above the mean tidal level and the lower mediolittoral, under the mean tidal level) (Bellan-Santini et al. 1994 in UNEP, 1998), the authors of this study recognized three distinct parts (horizons) of the mediolittoral zone (upper, middle and lower). Each horizon is characterized by different tidal levels and horizontal banding of particular kinds of organisms (Figure 2).

On each location, one site on limestone and one site on sandstone were selected at the four shore heights (supralittoral and upper, middle and low mediolittoral). At each site, three 10 x 10 cm replicate squares were used to estimate densities for each species separately at each of

these four heights. Only surfaces poor in vegetation and fauna, but abundant in chthamalids, were selected. Each square was scraped clean using a paint scraper. Samples were preserved in seawater-ethanol (80%) for later study. Determination of the samples took part in the laboratory, with stereo microscope, according to the works of Southward (1976) and Relini (1980) based on the morphological features. In this study, we took into consideration only the external morphological features, as follows: the shape of the opercular opening and of the adductor muscle scar and the position and the curvature of the articulation between terga and scuta. The collected material is kept in the laboratory of the Faculty of Education of Koper.

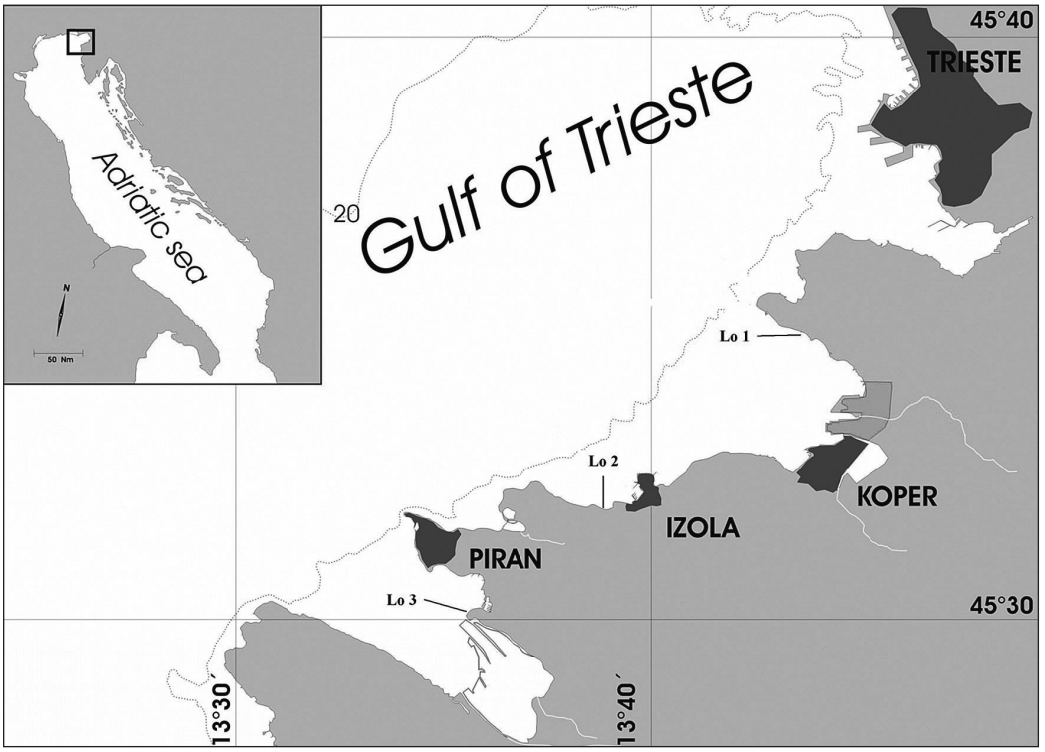


Figure 1: Map of the investigated area indicating sampling localities (Lo1, Lo2 and Lo3)
Slika 1: Zemljevid preučevanega območja z vrisanimi vzorčišči (Lo1, Lo2 in Lo3)

3. RESULTS AND DISCUSSION

Zonation patterns of the investigated sites

The **supralittoral zone** extends over a width of about 20 cm above the mean high water spring tide level (MHWS). The assemblages of this zone were represented mainly by the small prosobranchia periwinkle *Littorina neritoides* and the detritus feeding isopod *Ligia italica*. In its lower part, chthamalids associated to various communities of microscopic cyanobacteria (especially *Calothrix* sp.) were extended down to the mediolittoral zone.

The vertical extent of the **mediolittoral zone** was approximately 90 cm. It extends between the mean high water spring tide level (MHWS) and mean low water spring tide level (MLWS).

The **upper horizon** of this zone ranges from MHWS to mean high water neap tide level (MHWN) over a width of about 20 cm. It was characterized by dense populations of chtamalides and macrobenthic green algae communities (mainly belonging to the genera *Blidingia*, *Ulva*, *Chaetomorpha* and *Cladophora*).

The **middle horizon** extends from MHWN to mean low water neap tide level (MLWN) to over 40 cm in width. The chthamalids of this horizon were mixed with other faunal species as the gastropods (*Monodonta* sp., *Gibbula* sp.), limpets (*Patella* sp.) and anthozoans (*Actinia equina*). The most common macrobenthic algae were red algae belonging to the genera *Gelidium* and *Polysiphonia*. Among the green algae, the species *Ulva compressa* and *Cladophora* sp. were the most abundant. The most characteristic was the brown algae *Fucus virsoides* that generally occupies the entire horizon.

The **lower horizon** ranges from MLWN to MLWS. The width of this horizon was approximately 30 cm. It was mainly occupied by dense aggregates of the bivalve *Mytilus galloprovincialis* and by the green algae *Ulva laetevirens*.

The width of these zones and horizons were different in relation to the slope of the shore, variations in light and shade, exposure to waves, spray blown from waves and tidal range.

Description of the identified *Chthamalus* species

During the investigation, three different species of chthamalid barnacles were identified: *C. depressus*, *C. stellatus* and *C. montagui*. Table 1 illustrates the identification procedure of these three species based on external morphological features.

C. depressus

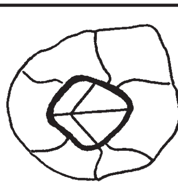
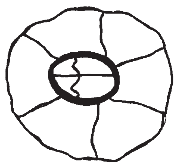
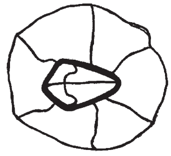
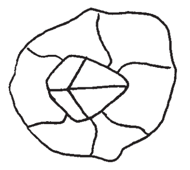
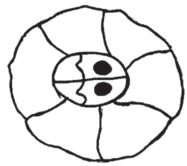
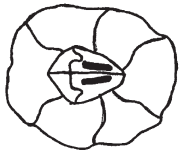
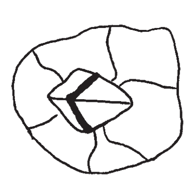
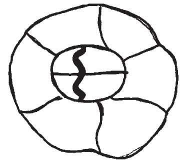
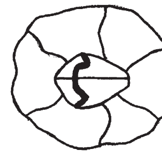
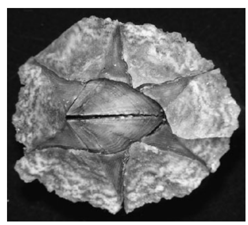
The shell is up to 10 – 12 mm in size and composed of 6 wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). The opercular opening is kite-shaped. The adductor muscle scare (visible on the scuta) is not deep, sometimes absent. The joint between the terga and scuta crosses the centre line less than one third of the opercular opening (from the carina to the rostrum). The tergum is bigger than the scutum. The apical angle is less than 90° (Relini 1980).

C. montagui

The shell of this species is of more angular appearance due to the kite-shaped opercular opening. It is up to 6 mm in size (max distance from the rostrum to the carina) and composed of 6 coarsely ridged wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). It is often difficult to distinguish the single plates owing to corrosion and overgrowth of algae, endolithic and epilithic cyanobacteria and lichens. Adductor muscle pits (visible on the scuta) are long, narrow and close to the occludent margin. The articulations between the terga and scuta cross the centre line quite close to the carina, less than one third the distance to the rostrum. Scuta are longer than wide, while terga are short and wide. The apical angle is usually less than 90° (Southward 1976, Relini 1980).

Table 1: General synoptic table indicating the basic external morphological features for identification of *C. depressus*, *C. stellatus* and *C. montagui*

Tabela 1: Splošna sinoptična tabela z osnovnimi morfološkimi značilnostmi za identifikacijo C. depressus, C. stellatus in C. montagui

Criteria for identification		***Chthamalus depressus***		***Chthamalus stellatus***		***Chthamalus montagui***	
Shape of the opercular opening		Kite-shaped		Oval or circular		Kite-shaped	
Adductor muscle pit		Not deep or absent		Wide, deep and rounded		Long, narrow and close to the occludent margin	
Articulation between terga and scuta	position	Less than one third of the opercular opening (from the carina to the rostrum)		One third or more of the opercular opening (from the carina to the rostrum)		Less than one third of the opercular opening (from the carina to the rostrum)	
	curvature	Forms an angle < 90° towards opercular opening		Convex towards rostral plate		Concave towards rostral plate	
Figure (60 x)							

C. stellatus

The shell of this species is of utterly round appearance, with oval or sub circular opercular opening. The distance from the rostrum to the carina is about 8 mm. The shell is composed of 6 coarsely ridged wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). The adductor muscle scare (visible on the scuta) is wide, deep and rounded. The joint between the terga and scuta crosses the centre line at one third or more the distance down from the carina to the rostrum and the main curve is convex towards the rostrum. The scutum is short and wide, while the tergum is very deep relative to its width. The apical angle is usually close to 90° (Southward 1976, Relini 1980).

Vertical distribution and abundance of *Chthamalus* species

According to the observations of the investigated sites, results showed that *Chthamalus* populations occupied distinct bands of the rocky shore, although the distribution and abundance of the single species, at various tidal levels, were different (Figure 2).

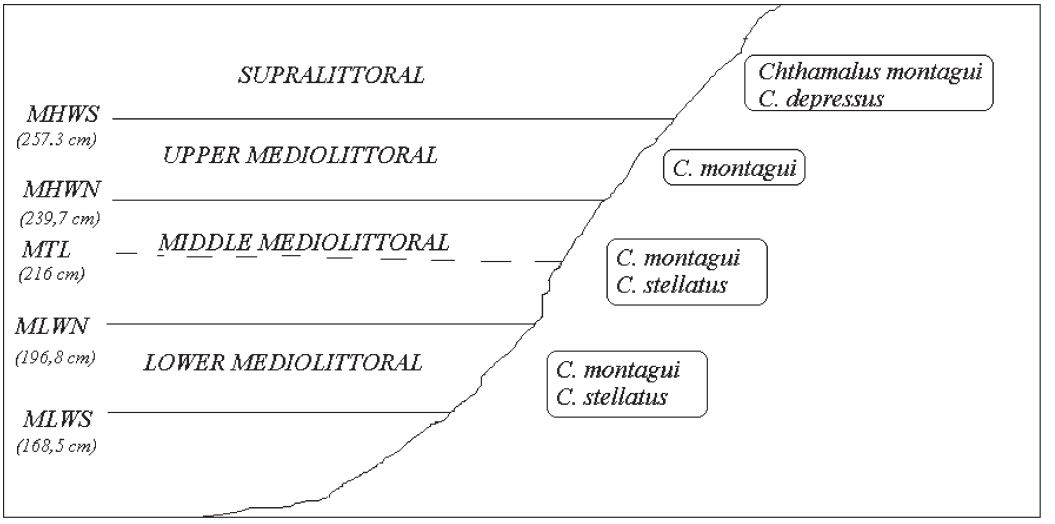


Figure 2: Figure shows the principal zones of the investigated sites and the distribution at various tidal levels on the shore of the identified *Chthamalus* species. (Legend: MHWS = Mean High Water Spring; MHWN = Mean High Water Neap; MTL = Mean Tide Level; MLWN = Mean Low Water Neap; MLWS = Mean Low Water Spring). (Source of mean values of the sea levels: Agencija RS za okolje 2009; analysis of data: Harpha Sea, d.o.o. 2006.)
Slika 2: Prikaz glavnih pasov preučevanih lokalitet in razširjenost identificiranih vrst iz rodu Chthamalus na različnih plimnih ravneh. (Vir srednjih vrednosti ravni morja: Agencija RS za okolje 2009; analiza podatkov: Harpha Sea, d.o.o. 2006.)

As illustrated in Figure 2, *C. depressus* was restricted only to the lower limit of the supralittoral zone and co-occurred with *C. montagui*. The species *C. stellatus* occurred only in the middle and in the lower horizon of the mediolittoral; while *C. montagui* had a great vertical distribution. It occupied all zones (from the lower part of the supralittoral to the lower horizon of the mediolittoral zone) and all tidal levels (from MHWS to MLWS).

In general, *C. montagui* tended to occupy slightly higher tidal levels and *C. stellatus* lower tidal levels, which is in accordance with the studies conducted by Southward (1976) and Crisp et al. (1981) for the Mediterranean (Figures 3 and 4).

The analysis of the percentage composition revealed that *C. montagui* was the most abundant species at all the levels and showed peaks in density in the upper and in the middle horizons of the mediolittoral on the selected substrata, limestone and sandstone. On limestone it was slightly more abundant in the supralittoral zone, while on sandstone it was more abundant in the lower horizon of the mediolittoral zone.

C. stellatus appeared to be very scarce in the middle horizon of the mediolittoral on limestone; while its abundance increased lower down, in the lower horizon, as stated in previous studies by Pannacciulli et Relini (2000) for the Italian part of the Gulf of Trieste, but in contrast with the studies by Benedetti-Cecchi et al. (2000) and Menconi et al. (1999). They claimed that *C. stellatus* was the most common sessile invertebrate in mediolittoral rocky shore assemblages of the northwest Mediterranean and that these organisms may occur at various heights on the shore but, on average, are more abundant in high-shore habitats.

On sandstone, *C. stellatus* occurred only in the lower horizon of the mediolittoral, but was less abundant than on limestone (Figures 3 and 4).

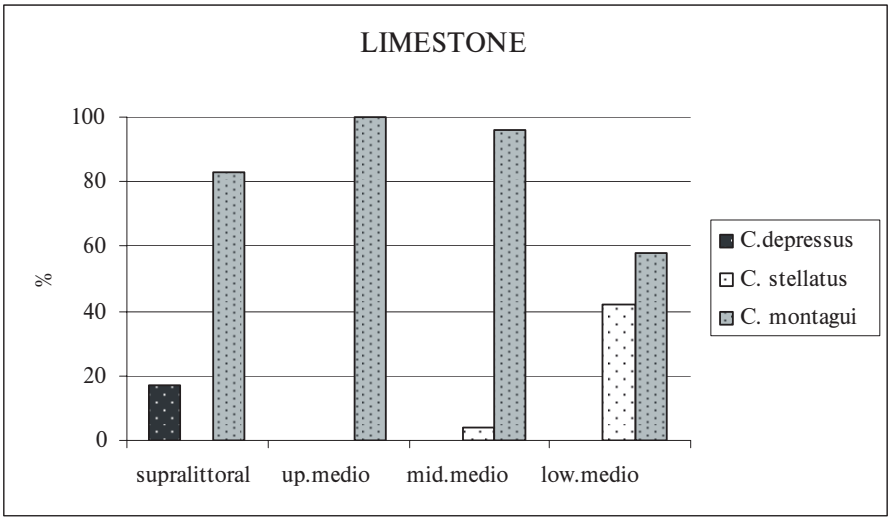


Figure 3: Percentage composition of C. depressus, C. stellatus and C. montagui at different heights on the shore (supralittoral, upper, middle and low mediolittoral) on limestone

Slika 3: Odstotna sestava vrst C. depressus, C. stellatus in C. montagui na različnih višinah obrežja (supralitoral, gornji, srednji in spodnji mediolitoral) na apnenčasti podlagi

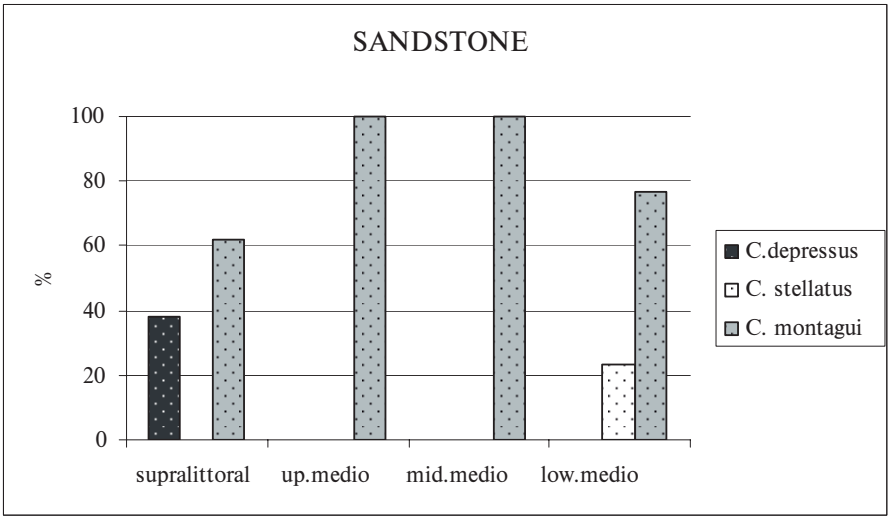


Figure 4: Percentage composition of C. depressus, C. stellatus and C. montagui at different heights on the shore (supralittoral, upper, middle and low mediolittoral) on the sandstone.

Slika 4: Odstotna sestava vrst C. depressus, C. stellatus in C. montagui na različnih višinah obrežja (supralitoral, gornji, srednji in spodnji mediolitoral) na peščenjaku

Figures 3 and 4 show that *C. depressus*, present only in the supralittoral zone, was more abundant on sandstone than on limestone.

Conclusions

On the bases of the carried out investigation it can be concluded that along the Slovene rocky shore:

1. *C. montagui* was significantly denser than *C. depressus* and *C. stellatus* on all investigated substrata and at all tidal levels.

2. *C. stellatus* density was always higher at low-tide level compared with the other tidal levels.

3. There were no significant differences between limestone and sandstone in vertical distribution and abundance of *Chthamalus* species.

4. SUMMARY

The present study deals with the vertical distribution of three species of Chthamalids, *Chthamalus depressus* (*Euraphia depressa*) (Poli, 1791), *Chthamalus stellatus* (Poli, 1791) and *Chthamalus montagui* Southward, 1976, which are the main constituents of the barnacle belt along the Slovene rocky shore (Gulf of Trieste, North Adriatic Sea). Chthamalids populations were monitored in spring 2008 on three sites along the Slovene coast (Koper bay, Izola bay and Piran bay). On each site two different kinds of substratum were selected (sandstone and limestone). Barnacles were counted up at four different shore heights (supralittoral and upper,

middle and lower mediolittoral). The result shows that *C. montagui* is present in the supralittoral and in the mediolittoral zone, but dominates especially in the upper and middle mediolittoral zone. *C. depressus* is present only in the supralittoral, while *C. stellatus* inhabits only the lower mediolittoral. A moderate difference in the number of single species among the sites and between the two different kinds of substratum was found. Thus the study presents a synoptic table for the identification of these three species, based on the external morphological features.

POVZETEK

Pričujoča študija obravnava vertikalno razširjenost treh vrst vitičnjakov, *Chthamalus depressus* (*Euraphia depressa*) (Poli, 1791), *Chthamalus stellatus* (Poli, 1791) in *Chthamalus montagui* Southward, 1976, ki so glavni graditelji pasu vitičnjakov na slovenskem morskem obrežju (Tržaški zaliv, severno Jadransko morje). Njihove populacije so bile spremljane spomladi 2008 na treh lokacijah vzdolž slovenske obale (Koprski, Izolski in Piranski zaliv). Na vsaki lokaciji sta bili izbrani dve vrsti podlage, peščenjak in apnenec. Vitičnjaki so bili prešteti na štirih različnih višinah obrežja (v supralitoralu in zgornjem, srednjem in spodnjem mediolitoralu). Rezultati so pokazali, da se vrsta *C. montagui* pojavlja v supralitoralu in mediolitoralu, a da prevladuje predvsem v zgornjem in srednjem mediolitoralu. *C. depressus* se pojavlja zgolj v supralitoralu, *C. stellatus* pa le v spodnjem mediolitoralu. Ugotovljena je bila majhna razlika v številu posameznih vrst med lokalitetami kot tudi med dvema različnima vrstama substrata. Študija tako predstavlja sinoptično tabelo za identifikacijo teh treh vrst, izdelano na osnovi zunanjih morfoloških značilnosti teh vitičnjakov.

5. LITERATURE

1. Agencija Republike Slovenije za okolje (2009): Morje. In: Kobold M., Uhan J., Trček R., Knez J. (eds): Hidrološki letopis Slovenije 2005. Agencija RS za okolje. Ljubljana. 213-220. http://www.arso.gov.si/vode/poro%c4%8dila%20in%20publikacije/Hidroloski%202005%20-%20II_del%20D.pdf (10. mar. 2009).
2. Battelli, C., N. Dolenc-Orbanić (2008): First record of *Chthamalus montagui* Southward, 1976 (Crustacea, Cirripedia) on the Slovenian coast (Gulf of Trieste, Northern Adriatic Sea). Ann, Ser. hist. nat. 18(1): 73-78.
3. Bellan-Santini, D., J.C. Lacaze, C. Poizat (1994): Les Biocénoses marines et littorales de Méditerranée. Synthese, menaces et perspectives. Museum National d'Histoire Naturelle. Paris. 264 pp.
4. Benedetti-Cecchi, L., S. Acunto, F. Bulleri, F. Cinelli (2000): Population ecology of the barnacle *Chthamalus stellatus* in the northwest Mediterranean. Mar. Ecol. Prog. Ser. 198: 157-170
5. Bussani, A., M. Celio, C. Comici (2003): Climatological analysis (1991-2002) of the thermohalines characteristics in the Marine Reserve of Miramare (Gulf of Trieste). Boll. Geof. Teor. Appl. 44(1):11-17
6. Crisp, D., A.J. Southward, E. Southward (1981): On the distribution of the intertidal barnacles *Chthamalus stellatus*, *Chthamalus montagui* and *Euraphia depressa*. J. mar. biol. Ass. U.K. 61: 359–380

7. Lipej, L., M. Orlando Bonaca, T. Makovec, (2004): Raziskovanje biodiverzitete v Slovenskem morju. Nacionalni inštitut za biologijo, Morska biološka postaja. Piran. 136 pp.
8. Malačič, V., M. Jeromel (2005): Vetrovi ob Slovenski obali-tablice. Nacionalni inštitut za biologijo, Morska biološka postaja. Piran. 2 pp.
9. Menconi, M., L. Benedetti-Cecchi, F. Cinelli (1999): Spatial and temporal variability in the distribution of algae and invertebrates on rocky shores in the northwest Mediterranean. J. Exp. Mar. Biol. Ecol. 233: l-23
10. Ogorelec, B., J. Faganeli, M. Mišič, B. Čermelj (1997): Recostruction of paleoenvironment in the Bay of Koper (Gulf of Trieste, Northern Adriatic). Ann. Istr. Medit. Studies, Nat. Hist. 11: 187-200
11. Pannacciulli, F.G., G. Relini (2000): The vertical distribution of *Chthamalus montagui* and *Chthamalus stellatus* (Crustacea, Cirripedia) in two areas of the NW Mediterranean Sea. Hydrobiologia 426: 105-112
12. Pavlovec, R. (1985): Numulitine iz apnencev pri Izoli (SW Slovenija). Razprave SAZU, IV. razred, 26: 219-230
13. Relini, G. (1980): Cirripedi Toracici. Guide per il riconoscimento delle specie animali delle acque lagunari e costiere italiane, 2. Report No. CNR-AQ-1/91. CNR. Roma. 118 pp.
14. Relini, G. (1981): Distribution of *Chthamalus montagui* in the Mediterranean Sea. Rapp. Comm. Int. Mer Medit. 27(2): 149-150
15. Southward, A.J. (1976): On the taxonomic status and distribution of *Chthamalus stellatus* (Cirripedia) in the northeast Atlantic region: with a key to the common intertidal barnacles of Britain. J. mar. biol. Ass. U.K. 56: 1007-1028
16. U.N.E.P. - P.A.M. 1998. Rapport reunion d'expert sur les types d'Habitats marins dans la region Méditerranéenne. UNEP (OCA) MEDW. 149/5. CAR/ASP, Tunis.
17. Zavodnik, D. (1998): Prilozi morskoj fauni Riječkog zaljeva. 7. Raci brumbuljci (Crustacea: Cirripedia: Balanomorpha) – Contributions to the marine fauna of Rijeka Bay (Adriatic Sea). 7. Barnacles (Crustacea: Cirripedia: Balanomorpha). In: Arko-Pijevac, M., Kovačić, M. Crnković, D. (eds.): Zbornik prirodoslovna istraživanja riječkog područja. Prirodoslovni muzej Rijeka. Rijeka. 633-637
18. Zavodnik, D., A. Pallaoro, A. Jaklin, M. Kovačić, M. Arko-Pijevac (2005): A benthos of the Senj Archipelago (North Adriatic Sea, Croatia). Acta Adriat. 46 (suppl. 2): 3-68

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