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VEGETATION OF THERMOPHILIC TRAMPLED HABITATS IN THE BAY OF KVARNER

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The vegetation of thermophilic trampled habitats was sampled in the Bay of Kvarner according to the standard procedures of the Braun-Blanquet method. The following associations were determined: *Polycarpo-Amaranthesetum deflexi* Pignatti 1953, *Euphorbio-Oxalidetum corniculatae* Lorenzoni 1964, *Euphorbietum maculatae* Poldini 1989, *Eleusinetum indicae* Pignatti 1953. Among them a new association was described: *Catapodio loliacei-Herniarietum rotundifoliae* ass. nova. The *Euphorbia prostrata* community, *Trifolium repens* community, and the *Cynodon dactylon* community were not assigned to the association. The ordination diagram (Princoor program) shows the main differences among the communities. On the first axis, there is a gradient from the most thermophilic *Cynodontetum dactylon* comm. and *Catapodio-Herniarietum* to the more mesophilous and less trampled *Polycarpo-Amaranthesetum* and *Euphorbio-Oxalidetum*. On the other axis, the gradient runs from floristically simple communities with only a few C4 species such as the *Polycarpo-Amaranthesetum* and *Cynodon dactylon* community to all other communities with more *Eragrostietalia* elements.

Key words: trampled community, vegetation, C4 plants, syntaxonomy, *Eragrostietalia*, *Stellarietea mediae*, Kvarner Bay, Croatia.

Čarni A. & N. Jogan: Vegetacija termofilnih gaženih staništa u Kvarnerskom zaljevu. Nat. Croat. Vol. 7, No 1., 45-58, 1998, Zagreb

Istraživanje vegetacije termofilnih gaženih staništa u Kvarnerskom zaljevu provedeno je po standardnoj Braun-Blanquetovoj metodi. Utvrđene su sljedeće zajednice: *Polycarpo-Amaranthesetum deflexi* Pignatti 1953, *Euphorbio-Oxalidetum corniculatae* Lorenzoni 1964, *Euphorbietum maculatae* Poldini 1989,

* N. Jogan was involved in the determination of some plants and contributed with about 20 % of the whole work.

Eleusinetum indicae Pignatti 1953. Pored njih je opisana i nova asocijacija: *Catapodio loliacei-Herniarietum rotundifoliae* ass. nova, te sastojine vrste *Euphorbia prostrata*, vrste *Trifolium repens* i vrste *Cynodon dactylon*. Dijagram (program Princoor) prikazuje gradijent od najtermofilnijih sastojina vrste *Cynodon dactylon* comm. i *Catapodio-Herniarietum* do mezofilnijih i manje gaženih *Polycarpo-Amarantheum* i *Euphorbio-Oxalidetum*. Na drugoj osi je prikazan gradijent od floristički najjednostavnijih zajednica sa nekoliko C4 vrsta, kao što su *Polycarpo-Amarantheum* i sastojine vrste *Cynodon dactylon*, pa sve do zajednica s više vrsta reda *Eragrostietalia*.

Ključne riječi: zajednice utrina, vegetacija, C4 biljke, sintaksonomija, *Eragrostietalia*, *Stellarietea mediae*, Kvarnerski zaljev, Hrvatska.

INTRODUCTION

Trampling is the action of man, animals, vehicles, and the like performed vertically on the ground and at the same time on the vegetation. There are several consequences, the main ones being (1) mechanical damage to tender tillers, (2) compression of the soil reducing aeration, and (3) limitation of the content of water in the ground. (WILMANN 1993). These consequences have little or no impact on trampling-resistant species, but their competitors are thus eliminated. The effect of trampling is reflected in the growth form of the plants. They adapt to these conditions by forming rosettes (*Plantago major*), stolons (*Cynodon dactylon*), creeping stems (*Herniaria* spp., *Euphorbia* spp.), dense tussocks (*Eragrostis* ssp.), etc.

The present work deals with a group of communities that develop in late summer. According to the list made by COLINS & JONES (1985), many species (*Amaranthus* spp., *Cynodon dactylon*, *Digitaria sanguinalis*, *Eleusine indica*, *Eragrostis* spp., *Euphorbia* spp., *Portulaca oleracea*, *Setaria* ssp.) possess the C4 assimilation pathway, advantageous in the conditions of high light intensity, high temperature, and low humidity that are characteristic of tropical and subtropical regions (ČARNI 1997).

In Europe, associations of trampled habitats are usually classified within *Polygono-Poetea annuae* Rivas – Martínez 1975. However, there is a group of thermophilic trampled communities appearing in trampled habitats in late summer. These communities, where species of *Stellarietea mediae* s. lat. outnumber those of *Polygono-Poetea annuae*, are classified within *Eragrostietalia* J. Tx. ex Poli 1966 and *Stellarietea mediae* R. Tx., Lohmeyer et Preising in R. Tx. 1950. (MUCINA 1993)

In the continental part of Croatia, trampled vegetation was studied by HORVAT (1962), MARKOVIĆ (1965), and RAUŠ et al. (1985) who dealt with communities of *Polygono-Poetea*. The only association that can be assigned to the presently studied group (*Eragrostietalia*) in the continental part is the *Eragrostio-Polygonetum* Oberdorfer 1954 found in the east of Croatia (RAUŠ et al. 1985).

In the Mediterranean part of Croatia, trampled vegetation is classified within *Hordeion leporini* of *Stellarietea mediae* (HORVAT 1963) and *Polygonion avicularis* Br.-Bl. 1931 ex Aich. 1933 of *Plantaginetea majoris* R. Tx. 1950 (MARKOVIĆ 1969). POLDINI (1989) proposed assigning the thermophilic trampled vegetation in northern Italy to *Polycarpion tetraphylli* Riv.-Mar. 1975, an alliance replacing *Polygonion avicularis* in the Mediterranean Basin. A survey of thermophilic trampled vegetation in Europe

was elaborated by ČARNI & MUCINA (1998). *Eragrostietalia* was divided into *Euphorbion prostratae* Rivas-Martínez 1976 from the Iberian Peninsula, *Polycarpo tetraphylli-Eleusinion indicae* Čarni & Mucina 1998 from the submediterranean region, and *Eragrostio-Polygonion arenastri* Couderc & Izco ex Čarni & Mucina 1998 from the temperate parts of Europe.

So far, the following trampled associations have been recorded along the coast of Croatia: *Hordeetum leporini* Br.-Bl. 1936, *Lolio-Plantaginetum commutatae* Horvatić 1934, and *Sclerochloëtum durae* Br.-Bl. 1931. These relevés were taken in spring and early summer, whereas the vegetation of the *Eragrostietalia* develops in late summer. There are also several records of thermophilic trampled vegetation from this region made by SCHULTE (1989) and ČARNI (1996).

STUDY AREA AND METHODS

The Bay of Kvarner (Fig. 1) lies between the Istrian Peninsula and the Velebit mountain range. There are numerous islands in the Bay of Kvarner including Cres, Lošinj, Krk, and Rab, to mention only the largest.

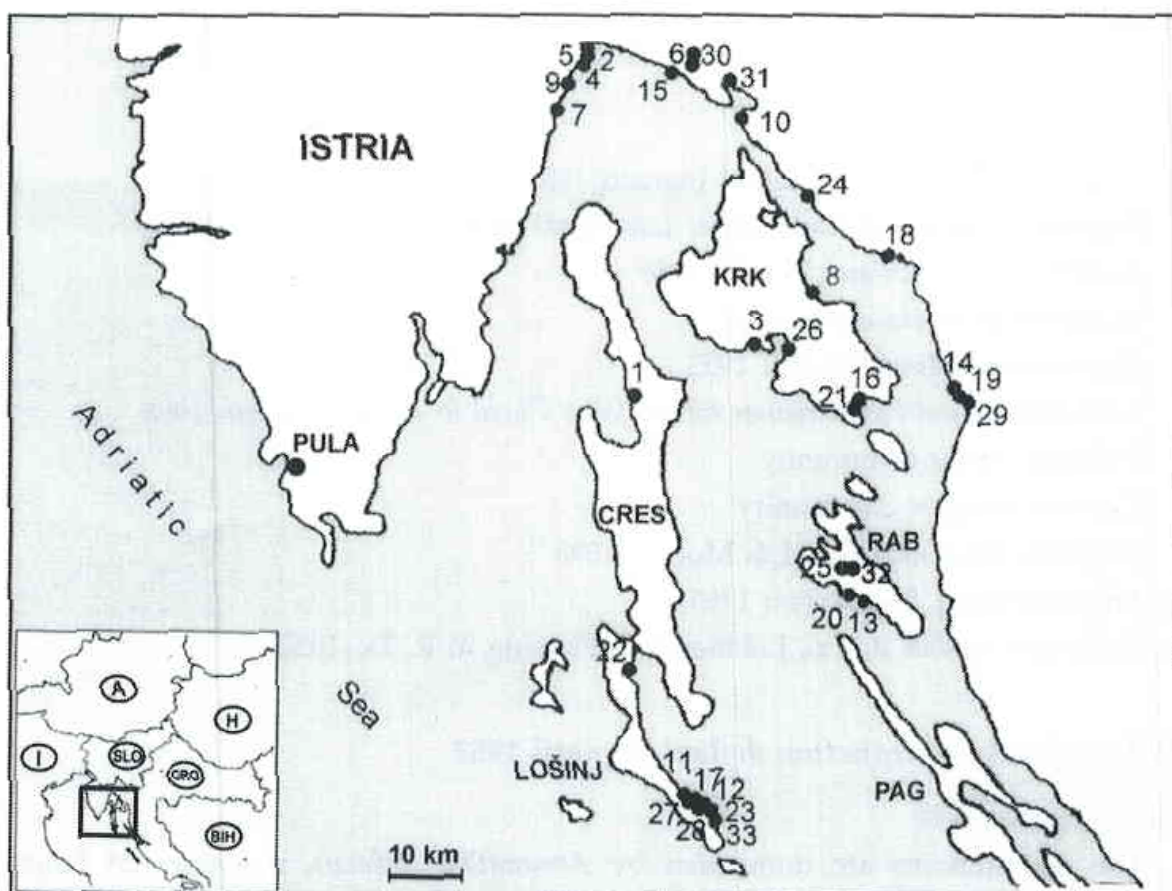


Fig. 1. Localisation of relevés. Numbers correspond to those in Table 1.

The climate is classified within the group of moderately warm and humid climates: Csa according to ŠEGOTA (1988). This is a Mediterranean climate with hot summers. The annual precipitation is 1595 mm in Rijeka, 1200 mm in Kraljevica, and 1353 mm in Senj. The average annual temperature is 14.0 °C in Rijeka, 13.6 °C in Kraljevica, and 14.4 °C in Senj (WALTER & LEITH 1960). The sea surface temperature is about 10 °C in winter and over 23 °C in summer. The salinity is about 37 (ROGIĆ 1962).

The potential natural vegetation is *Quercus-Carpinetum orientalis* Horvatić 1939, with *Q. pubescens*, *Q. cerris*, and *Carpinus orientalis* as dominant species.

The phytosociological relevés were made and elaborated according to the standard procedures of the Braun-Blanquet method (BRAUN-BLANQUET 1964). The nomenclature of the plants follows DOMAC (1994), except *Bromus molliformis* Lloyd., *Conyza albida* Willd., *Coronopus didymus* (L.) Sm., *Eleusine indica* Gaertner, *Euphorbia prostrata* Aiton and *Tagetes minutus* L..

The ordination (principal coordinates analysis using similarity ratio as resemblance) of all the relevés was performed using the PRINCOOR program from the SYN-TAX 5.0 package (PODANI, 1993, 1994). The relevés were made by using the Braun-Blanquet sampling scale which was transformed into an ordinal 0–9 scale according to VAN DER MAAREL (1979).

RESULTS

Syntaxonomical scheme

Polycarpo-Amaranthesium deflexi Pignatti 1953

Euphorbio-Oxalidetum corniculatae Lorenzoni 1964

Euphorbietum maculatae Poldini 1989

Euphorbia prostrata community

Eleusinetum indicae Pignatti 1953

Catapodio loliacei-Herniarietum rotundifoliae Čarni in Čarni & Jogan 1998

Trifolium repens community

Cynodon dactylon community

Polycarpo-Eleusinion Čarni & Mucina 1998

Eragrostietalia J. Tx. ex Poli 1966

Stellarietea mediae R. Tx., Lohmeyer & Preising in R. Tx. 1950

Polycarpo-Amaranthesium deflexi Pignatti 1953

(Table 1, cols. 1–4)

The communities are dominated by *Amaranthus deflexus*, a species of South American origin that is widespread and naturalized in warm regions all over the world. The association was described for the first time in northern Italy (PIGNATTI

1954). The habitats of this community can be found along the foot of walls and in similar sites. In comparison with the following communities, these sites are less trampled.

***Euphorbio-Oxalidetum corniculatae* Lorenzoni 1964**

(Table 1, cols. 5–8)

Like the preceding entry, this is also an association of less trampled and shady habitats. It appears along the foot of walls and at the edges of footpaths in old towns, on street verges, etc. This association was described in northern Italy (LORENZONI 1964) and is quite common in the region studied. It has already been found in the town of Krk (SCHULTE 1989: Table 5/2,3)

***Euphorbietum maculatae* Poldini 1989**

(Table 1, cols. 9–11)

Euphorbia maculata is a small prostrate summer annual species of North American origin. This species, together with several other more or less prostrate annuals with small stipules (e.g. *E. maculata*, *E. prostrata*, *E. humifusa*), is often considered the separate genus *Chamaesyce* (BENEDI & ORELL 1992).

The sites of this association are drier and warmer than those of the first two associations mentioned. The trampling is also more extensive. The habitats of this association are very similar to those covered by *Eleusinetum indicae*.

In this community in the Ičići marina, *Coronopus didymus* was found; this is an adventitious species of South American origin spread throughout Europe. According to TRINAJSTIĆ (1995), this species has only one locality in Croatia. It was found in Gračac about 120 years ago. However, according to its general secondary distribution (in the warmer parts of Europe and especially in the Mediterranean Basin where it is naturalized and relatively frequent), we can assume that it is much more widespread in the Mediterranean region of Croatia. This assumption can be supported by a few additional localities found recently in Slovenia (several localities in Ljubljana and Izola) and in Croatia (Lopar on Rab island) (JOGAN unpublished).

***Euphorbia prostrata* community (Table 1, col. 12)**

Euphorbia prostrata is also an annual, procumbent species often appearing on synanthropic sites with characteristic soils that are subject to frequent trampling (BENEDI & ORELL 1992). It is of Central American origin and forms communities in warm and temperate regions. The communities in tropical and subtropical regions are classified within *Ruderali-Manihotetea* Léonard in Tanton 1949 (ČARNI 1995, 1997). *Euphorbia prostrata* is common in trampled communities in the Mediterranean

region, and it has also expanded intensively in warmer temperate regions (TRPIN 1995).

In the Bay of Kvarner, only one community dominated by *Euphorbia prostrata* was sampled, in Mali Lošinj, along a road in the gutter between the sidewalk and the pavement. Since Lošinj is among the warmest parts of the Bay of Kvarner, it can be expected that towards the south there are more communities dominated by this species. With the collection of more material, the syntaxonomical classification of this community will be clearer.

Eleusinetum indicae Pignatti 1953

(Table 1, cols. 13–15)

Eleusine indica is an annual, caespitose tropical grass originating in southwestern Asia that has become naturalized and widespread in the warmer regions of Southern and Central Europe. It is found along the coast and in the Pannonian part of Croatia (VREŠ 1996)

The ecological conditions of the habitat of this community are similar to those of *Euphorbietum maculatae*. It thrives in pavement fissures filled with fine sand and some humus.

Catapodio loliacei-Herniarietum rotundifoliae Čarni in Čarni & Jogan ass. nova hoc loco

(Table 1, cols. 16–23)

Herniaria rotundifolia is an endemic species on the Kvarner islands and along the Croatian coast. It belongs to the complex shapes of *Herniaria glabra* agg. It can be distinguished from typical *Herniaria glabra* by its leaves, calyx, and fruits (TRPIN 1973).

These communities can be found in cracks between rocky slabs in coastal streets and piers in the region. From the ecological point of view, the habitats of these communities are among the driest and hottest of all the communities treated. The nomenclatural type is relevé 18, Table 1. The character species is *Herniaria rotundifolia* and *Catapodium loliaceum* the differential relative to other trampled communities from this group. The community is relatively common in the region.

A similar floristic composition can also be found in the *Herniario odoratae-Eragrostietum minoris* R. Tx. et Prsg. (1942) 1950 growing in Ukraine. It was assigned by R. Tüxen to the suballiance *Eragrostidion*. It grows in warm sites rich in nitrates. The character species are *Eragrostis minor*, *Herniaria odorata*, *Eragrostis pilosa*, *Amaranthus viridis*, *Portulaca oleracea*, *Setaria verticillata*, etc. (TÜXEN 1950)

In Europe, two communities dominated by *Herniaria glabra* have been described. The *Herniarietum glabrae* (Hohenester 1960) Hejny et Jehlík 1975 was described in Central Europe and assigned to *Polygono-Poetea* (HEJNY & JEHLÍK 1975). The *Herniaria glabra* community from northern Italy has the same syntaxonomical position (syn. *Herniarietum glabrae* Poldini 1980 non Hejny et Jehlík 1975) (POLDINI 1989).

Trifolium repens community

(Table 1, cols. 24–25)

The *Trifolium repens* community was not treated as an association, since the ecological amplitude of the dominant species is too wide. The sites are dry and warm. The same community was sampled in the town of Krk by SCHULTE (1989, relevé 66).

Cynodon dactylon community

(Table 1, cols. 26–33)

The species *Cynodon dactylon* forms nearly monodominant stands on dry sites and propagates with long stolons. This species is resistant to some herbicides (MUCINA 1993).

In continental Europe, communities dominated by *Cynodon dactylon* are classified within *Planagini-Cynodontetum* Brun-Hool 1962 nom. inv. The following species can be found in these communities: *Cynodon dactylon*, *Lolium perenne*, *Polygonum aviculare*, *Chenopodium album*, *Plantago major*, *Amaranthus retroflexus*, *Conyza canadensis*, and *Artemisia vulgaris*, to mention only the most common (MOCHNACKY 1991)

POLDINI (1980, 1989) classified communities dominated by *Cynodon dactylon* within *Conyzo-Cynodontetum*. *Conyzo-Cynodontetum* was described on railway stations in Slovakia by ELIAŠ (1978). These communities were classified within *Agropyreteae intermedii-repentis*. They appear on less intensively trampled dry and warm sites. The most common species in these communities are *Convolvulus arvensis*, *Taraxacum officinale*, *Rubus caesius*, *Conyza canadensis*, and *Artemisia vulgaris* (ELIAŠ 1978).

The *Cynodon dactylon* community thrives in the warmest places that are fully exposed to the sun's radiation. The habitats are unfavourable: dry and extremely trampled. For this reason, these communities are floristically among the poorest. The community is common in the territory discussed. We decided not to describe a new association since the ecological niche of *Cynodon dactylon* is broader in the Mediterranean region of Europe where *Cynodon dactylon* enters many more syntaxonomically different communities than in Central Europe (MARKOVIĆ pers. com.).

The *Cynodon dactylon* community is well differentiated by submediterranean species: *Conyza albida*, *Polycarpo-Amaranthesium tetraphyllum*, and *Hordeum leporinum*. In *Planagini-Cynodontetum*, many species characteristic of other orders of *Stellarietea mediae* can be found that do not appear in the *Cynodon dactylon* community such as *Galinsoga parviflora*, *Capsella bursa-pastoris*, *Bromus tectorum*, *Diplotaxis muralis*, *Achillea millefolium*, *Tripleurospermum inodorum*, *Atriplex patula*, *Achillea millefolium*, and many others (MOCHNACKY 1991).

The communities sampled by SCHULTE (1989: Table 1/1–3, Table 2/1–5, Table 7/1–3) in Rovinj and Krk can be assigned to the same community.

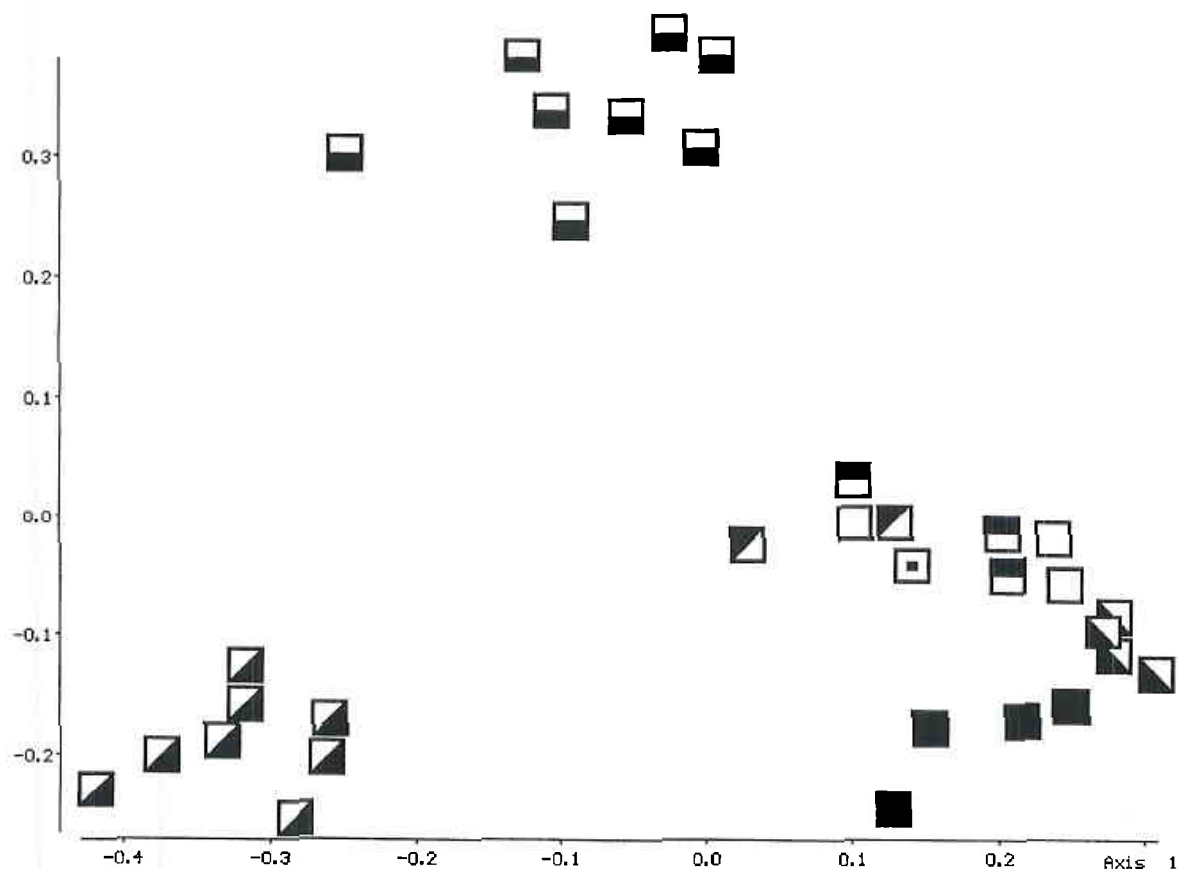


Fig. 2. Ordination diagramme. Legend: ■ – *Polycarpo-Amaranthesetum*, □ – *Euphorbio-Oxalidetum*, ▤ – *Euphorbietum maculatae*, ▥ – *Eleusinetum indicae*, ▦ – *Euphorbia prostrata* comm., ▧ – *Trifolium repens* comm., ▨ – *Catapodio-Herniarietum* and ▩ – *Cynodon dactylon* comm.

Ordination

The ordination diagram of the relevés reveals along the abscissa a gradient from the *Cynodon dactylon* community and *Catapodio loliacei-Herniarietum rotundifoliae* thriving in the driest and most trampled sites to the *Euphorbio-Oxalidetum* and *Polycarpo-Amaranthesetum deflexi* of the more mesic and less trampled sites. The ordinate shows the gradient from the species-poor communities of the *Cynodon dactylon* community and *Polycarpo-Amaranthesetum deflexi* to other, species-rich communities. Since the species are not linear variables, a horseshoe effect is precipitated on the ordination plane (PODANI 1994). This explains the quite distant position of *Catapodio-Herniarietum* on the ordinate.

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APPENDIX

Legend: 1. Cres, in the port; 2. Volosko, in the port; 3. Krk Island, Krk between the port and bus station; 4. Opatija, Viktora cara Emina Street; 5. Volosko, in the street above the church; 6. Rijeka, Trsat, in front of the church; 7. Lovran, in front of the hotel Excelsior; 8. Krk Island, Vrbnik, in front of the church, Vitezovićeve ul.; 9. Ičići, in the marina; 10. Kraljevica, along the street near the Veritas restaurant; 11. Mali Lošinj, in the port; 12. Mali Lošinj, along the road to Veli Lošinj; 13. Rab Island, Rab; 14. Senj, Pavlinski trg; 15. Rijeka, in the port; 16. Baška, along the path; 17. Mali Lošinj, on the coast; 18. Novi Vinodolski, in the port; 19. Senj, in the port; 20. Rab Island, the church of St. Euphemia, 21. Baška, in the port, 10 m²; 22. Nerezine, Obala nerezinskih pomoraca; 23. Veli Lošinj, on a path; 24. Crikvenica, on the channel; 25. Rab Island, St. Peter; 26. Punat, Hotel Park parking lot; 27. Mali Lošinj, on the sand at the shore; 28. Mali Lošinj, in front of the local church; 29. Senj, in the port; 30. Rijeka, Trsat; 31. Bakar, on the sand at the shore; 32. Rab, St. Peter; 33. Veli Lošinj, in front of the local church.

Less common species: 1. *Melilotus albus*, *Solanum luteum*, 3. *Geranium rotundifolium*, *Senecio vulgaris*, 5. *Amaranthus graecizans*, 5. *Rorippa sylvestris*, 6. *Tagetes minutus*, 7. *Bromus molliformis*, *Stellaria mediae*, 9. *Coronopus didymus*, 11. *Inula viscosa*, 13. *Anagallis arvensis*, 15. X *Festulolium*, 17. *Lagurus ovatus*, 17. *Trifolium campestre*, 18. *Atriplex hastata*, 18. *Juncus tenuis*, 18. *Poa sylvicola*, 24. *Morus* sp., 24. *Trifolium pratense*, 27. *Ajuga chamaepytis*, 27. *Polycnemum maius*, 31. *Daucus carota*, 32. *Bromus madritensis*, 32. *Carex stellulata*, 32. *Trifolium pratense*, *Verbascum* sp.

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SAŽETAK

Vegetacija termofilnih gaženih staništa u Kvarnerskom zaljevu

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Istraživanje vegetacije termofilnih gaženih staništa u Kvarnerskom zaljevu je provedeno po standardnoj Braun-Blanquetovoj metodi. Klima je na tom području umjereno topla (prosječna godišnja temperatura 14 °C) i vlažna (1600 mm oborina godišnje). Prirodnu vegetaciju čini uglavnom zajednica *Quercus-Carpinetum orientalis* Horvatić 1939 u kojoj dominiraju vrste *Quercus pubescens*, *Quercus cerris* i *Carpinus orientalis*.

Čovjek, životinja ili vozilo prilikom gaženja djeluju okomito na tlo i time ujedno na vegetaciju. Kao posljedice takovih postupaka su mehaničke ozljede izdanaka i tiješćenje zemlje te s tim povezano smanjivanje količine zraka i vode u tlu (WILMANN, 1993).

U radu su obrađene zajednice koje se pojavljuju na gaženim staništima u kasno ljeto. U skladu s indeksom koji su izradili COLINS & JONES (1985) u tim zajednicama pojavljuje se mnogo C 4 vrsta (*Amaranthus* ssp., *Cynodon dactylon*, *Digitaria sanguinalis*, *Eleusine indica*, *Eragrostis* ssp., *Euphorbia* ssp., *Portulaca oleracea*, *Setaria* ssp.), koje su prilagođene uvjetima intenzivne osvjetljenosti, visokim temperaturama i niskoj vlažnosti.

Većina zajednica gaženih staništa koje susrećemo u Europi spada u razred *Polygono-Poetea annuae* Rivas-Martinez 1975, dok termofilne zajednice istih staništa, koje se pojavljuju u kasno ljeto, uvrštavamo u *Eragrostietalia* J. Tx. ex Poli 1966 i *Stellarietea mediae* R. Tx., Lohmeyer et Preisling in R. Tx. 1950. Zajednice koje uspijevaju u Kvarnerskom zaljevu spadaju u svezu *Polycarpo-Eleusinion* Čarni & Mucina 1998.

Ta sveza obuhvaća zajednice gaženih staništa na područjima gdje dominira submediteranska klima.

Na području obuhvaćenom istraživanjima su utvrđene sljedeće zajednice: *Polycarpo-Amaranthesetum deflexi* Pignatti 1953 i *Euphorbio-Oxalidetum corniculatae* Lorenzoni 1964, koje nalazimo u starim gradskim predjelima i uz rubove cesta; *Euphorbietum maculatae* Poldini 1989, *Eleusinetum indicae* Pignatti 1953 i sastojine vrste *Euphorbia prostrata* susrećemo na sušnijim, toplijim i više gaženim mjestima nego prethodne dvije zajednice. Na najsunčanijim i intenzivno gaženim staništima zabilježili smo: *Catapodio loliacei-Herniarietum rotundifoliae* ass. nova, sastojine vrste *Trifolium repens* i vrste *Cynodon dactylon*.

Dijagram (program Princoor) prikazuje gradijent od najtermofilnijih sastojina vrste *Cynodon dactylon* comm. i *Catapodio-Herniarietum* do mezofilnijih i manje gaženih *Polycarpo-Amaranthesetum* i *Euphorbio-Oxalidetum*. Na drugoj osi je prikazan gradijent od floristički najjednostavnijih zajednica sa nekoliko C4 vrsta, kao što su *Polycarpo-Amaranthesetum* i sastojine vrste *Cynodon dactylon*, pa sve do zajednica sa više vrsta reda *Eragrostietalia*.