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Habitat mapping of Protected Landscape of Donji Kamenjak, Istria (Croatia)

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ABSTRACT

The aim of this research was to produce a georeferenced map of habitats of the Protected Landscape of Donji Kamenjak (Istria, Croatia). There were found 20 habitat types according to the National Classification of Habitats with the corresponding codes. The presence of habitat types and vegetation was determined on the basis of characteristic and dominant species. On a relatively small area, a large number of plant communities were found. The vegetation is represented mainly by coastal evergreen forests and maquis with *Juniperus oxycedrus* L., *Pinus halepensis* Mill., *Quercus ilex* L., *Erica arborea* L. and the eastern Adriatic shrubby habitats of *Cisto-Ericetalia* Horvatić 1958. A total of 76.49 ha was identified as belonging to Natura 2000 ecological network habitats, representing 18.78% of the total area of Donji Kamenjak. These are mainly rocky pastures of the *Chrysopogoni-Euphorbietum nicaeensis* Horvatić (1956) 1958 plant community, dominated by heliophilous plants which significantly enrich plant and landscape diversity. However, these are endangered habitats due to the abandonment of traditional system of sheep farming causing the occurrence of different succession stages and the development of the maquis and forests, pointing out the remarkable importance of traditional systems in biodiversity conservation.

Keywords: biodiversity, conservation, geographic information system, grazing, Natura 2000, vegetation

INTRODUCTION

Protected Landscape of Donji Kamenjak (further on PLDK) and Medulin archipelago has been protected since 1996. More than 500 vascular plant species have been recorded in earlier floristic researches (Tommasini, 1873; Freyn, 1877; Perko, 1998; Starmühler, 1998, 2004, 2010; Topić and Šegulja, 2000; Hršak et al., 2011), among which many are protected at national level (Vuković et al., 2011, 2013; Anonymus, 2013a, b). Therefore, Rt Kamenjak as a southernmost promontory of PLDK was recently proclaimed as Important Plant Areas (IPA) as an important area of plant diversity for the Republic of Croatia (Vuković, 2010). One of the most significant natural resources of PLDK is the present vegetation which determines the diversity of present biocenoses. Therefore, knowing the exact spatial distribution of vegetation is very important in the context of sustainable management of habitats, with special emphasis on Natura 2000 habitats. Due to the surface area and the available human resources, vegetation mapping of PLDK habitats using traditional methods lasted longer with higher material costs. Using the remote sensing images is therefore helpful and can be used for mapping vegetation of plant cover and habitats. More specifically, the potential of remote sensing vegetation research is often discussed (Van den Borre et al., 2011), which is reflected in many pilot studies (Bock et al., 2005; Förster et al., 2008; Spanhove et al., 2012; Mücher et al., 2013). In terrestrial ecosystems, most of the habitat cover is determined by the presence of

particular vegetation types. The aim of this study was to produce a PLDK habitat map and accordingly to develop guidelines for sustainable management of habitats based (among others) on optimal intensity of sheep grazing as an important feature for habitat and plant diversity sustainability. Such a vectorial map of habitats allows the following: 1. integration into the Geographic Information System (GIS) database and monitoring of Natura 2000 habitats, 2. spatial zoning of PLDK according to the type of habitat present and 3. spatial analysis of other vegetation cover contents.

MATERIALS AND METHODS

Study area

PLDK is an exceptional example of biodiversity in the Mediterranean part of Croatia and part of the habitat belongs within the Directive on the conservation of the natural habitats and flora of Natura 2000. It is located on the southernmost part of Istrian peninsula (Croatia), south of Premantura village and includes 14 uninhabited islets. The promontory on the southernmost part of PLDK, known as Rt Kamenjak is especially interesting (Figure 1). The surface area of PLDK is about 4 km^2, and is characterized by a Mediterranean climate. Due to its well-indented and long coastline, it almost has the climatic characteristics of an island. The vegetation field research was carried out on the PLDK, including the mainland and seven islets: Fenoliga, Porer, Fener, Šekovac, Ceja, Trumbuja and Bodulaš (Figure 1).

Identification of flora and vegetation was made during a six-month vegetation period, from April to October 2014. The vegetation cover was determined on the basis of dominant and characteristic plant species, using Guidance on the Determination of Terrestrial Habitats in Croatia according to the Habitats Directive of the European Union (Nikolić, 2006; Topić and Vukelić, 2009). The surfaces with homogeneous vegetation were selected and the sampling was done on 10 x 10 m plots for open grassland and 20 x 20 m for forest vegetation types.

Figure 1. The geographical position of Protected Landscape of Donji Kamenjak and Medulin archipelago in Croatia

Collected plant material is stored in the Herbarium of the Faculty of Agriculture, University of Zagreb (ZAGR) according to Bogdanović et al. (2016). Types of habitats are harmonized according to the 4th revised version of the National Classification of Habitats (NN 88/14) with the corresponding (NCH) codes. Protected habitats are presented together with a Natura 2000 code (Topić and Vukelić, 2009) according to Interpretation Manual of European Union Habitats - EUR28, 2013. Only naturalized and mostly invasive woody plant taxa according to Flora Croatica Database (Nikolić, 2019) and Boršić et al. (2008) were recorded as point locations.

The mapping of the habitat was carried out by a remote sensing method based on visual photo interpretation using the recent digital ortophoto footage (Geo-portal of the State Geodetic Administration – accessible on http://geoportal.dgu.hr/).

The final vector shapefile (shp) layer was constructed using the raster model interpolation method, while the official HTRS96/Croatia TM-EPSG: 3765 coordinate system was used as a reference. Based on the resulting polygon layer, a subsequent field trip was performed to interpret and control the results obtained by classifying the orthophoto images. The minimum polygon of mapping was set to 2.25 ha, but it was digitized even smaller important areas of habitat.

RESULTS

A total digitized area of PLDK with seven islets is 407.27 ha. A total of 20 habitat types and one epilitoric habitat (with no NCH code) inhabited by critically endangered species have been identified. The map of PLDK habitats is shown on Figure 2, with a legend of habitat types shown on Figure 3.

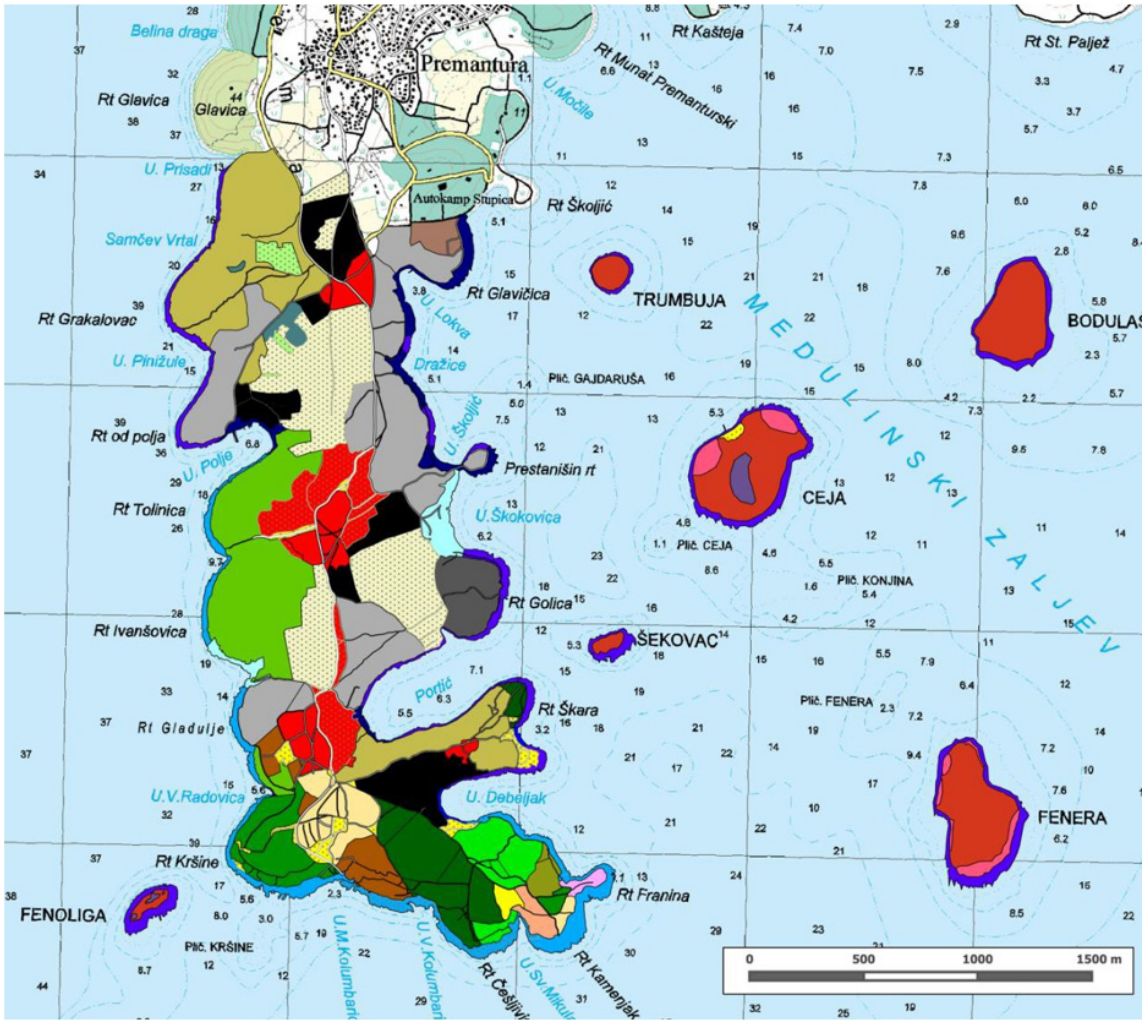

Figure 2. Habitat map of Protected Landscape of Donji Kamenjak and Medulin archipelago

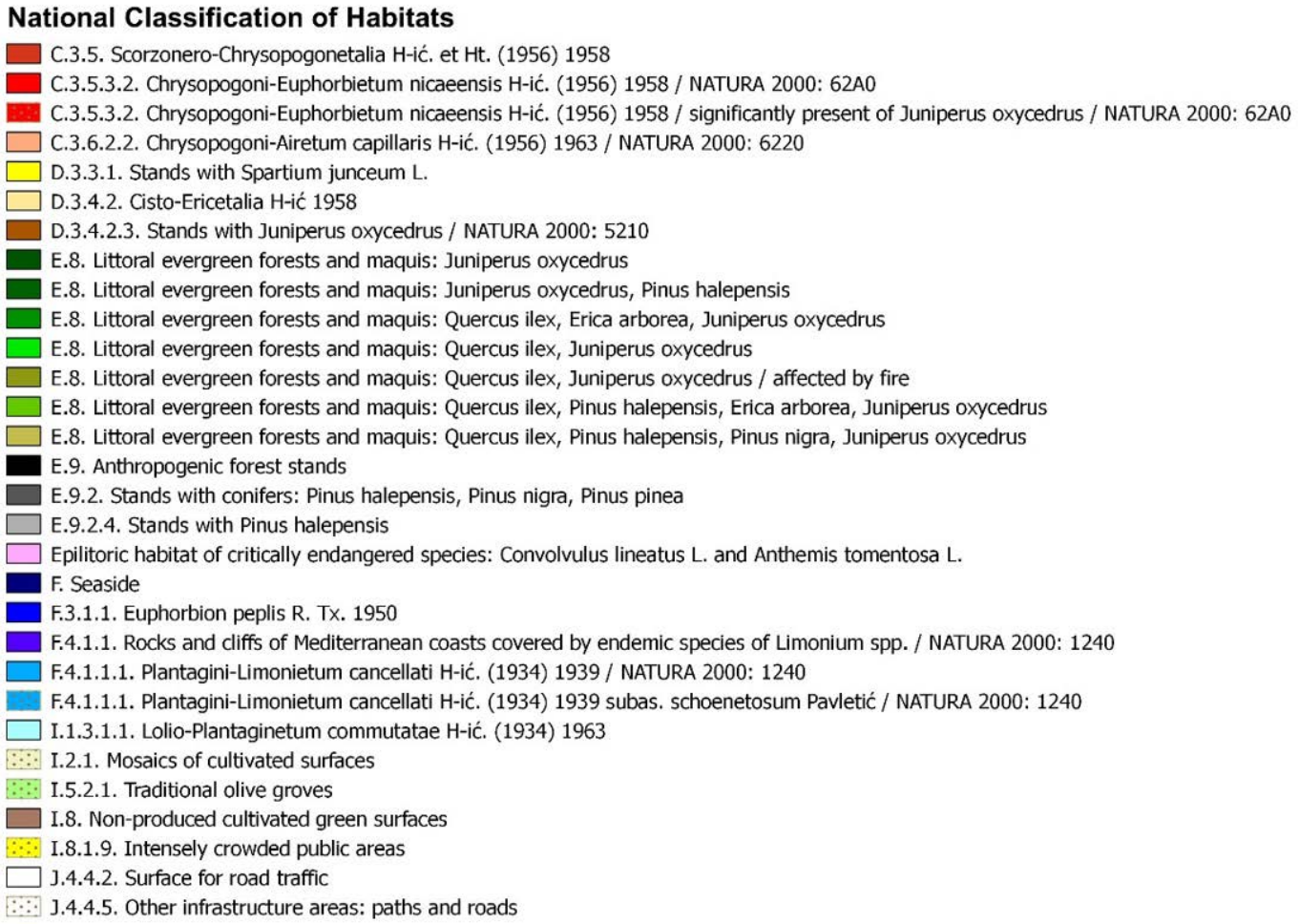

Figure 2. Legend of habitat types of Protected Landscape of Donji Kamenjak and Medulin archipelago

Identified habitat types of the PLDK (with the corresponding NCH and Natura 2000 codes) with the overall surface area are shown in Table 1.

On the digitized PLDK area, the most represented habitats are Littoral evergreen forests and maquis, occupying about 113 hectares. The species most commonly represented are *Pinus helepensis*, *P. nigra*, *P. pinea*, *Quercus ilex*, *Juniperus* spp., *Erica arborea* and others, followed by Dry grasslands occupying about 67 hectares. This includes eastern sub-mediterranean dry grasslands protected within Natura 2000 habitats. The dominant species are *Chrysopogon gryllus*, *Euphorbia nicaeensis*, *E. cyparissias*, *Potentilla recta*, *Dianthus carthusianorum*, *Scorzonera villosa*, *Festuca lapidosa*, *Plantago holosteum*, *P. lanceolata*, *Knautia illyrica*, *Achillea virescens*, *Bromus erectus* and others.

Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp. also occupy a significant part of PLDK (about 45 ha). These are Natura 2000 habitats overgrown with *Limonium cancellatum*, *Plantago holosteum*, *Chaenorrhinum minus*, *Crithmum maritimum* and others.

On the area of PLDK (Ljubičić et al., 2015; Paulik, 2016) it was established that 76.49 ha belongs to Natura 2000 habitats, representing with 18.78% of the total PLDK area (Figure 4).

Only naturalized and mostly invasive woody plant species: *Ailanthus altissima*, *Arundo donax*, *Carpobrotus acinaciformis* and *Robinia pseudoacacia*, were mapped (Figure 5).

Table 1. Habitat types of the Protected Landscape of Donji Kamenjak and Medulin archipelago

NCH code	NATURA 2000 code	Description of habitat types with characteristic species	Surface (ha)
C.3.		**Dry grasslands**	**67.63**
C.3.5.		*Scorzonero-Chrysopogonetalia* Horvatić et Horvat (1956) 1958	36.56
C.3.5.3.2.	62A0 Eastern sub-mediteranean dry grasslands	*Chrysopogoni-Euphorbietum nicaeensis* Horvatić (1956) 1958 **Characteristic species:** *Chrysopogon gryllus, Euphorbia nicaeensis, E. cyparissias, Potentilla recta, Dianthus carthusianorum, Scorzonera villosa, Festuca lapidosa, Plantago holosteum, P. lanceolata, Knautia illyrica, Achillea virescens, Bromus erectus, B. condensatus, B. madritensis, Dichanthium ischaemum, Galium lucidum*	12.63
C.3.5.3.2.	62A0	*Chrysopogoni-Euphorbietum nicaeensis* Horvatić (1956) 1958/ significantly present of *Juniperus oxycedrus*	16.28
C.3.6.2.2.	6220 Pseudo- steppe with grasses and annuals of the *Thero-Brachypodietea*	*Chrysopogoni-Airetum capillaris* Horvatić (1956) 1963 **Characteristic species**: *Chrysopogon gryllus, Aira elegantissima, Anthoxanthum ovatum, Hypochoeris glabra, Lupinus micranthus, Tuberaria guttata, Plantago bellardi, Galium parisiense, G. divaricatum, Vulpia ciliata, Lotus angustissimus, Gastridium ventricosum*	2.16
D.3.		**Mediterranean underbrush**	**16.55**
D.3.3.1.		Stands with *Spartium junceum* L.	1.10
D.3.4.2.		*Cisto-Ericetalia* Horvatić 1958	8.21
D.3.4.2.3.	5210 Arborescent matorral with *Juniperus* spp	Stands with *Juniperus oxycedrus*	7.24
E.		**Woods**	**197.09**
E.8.		Littoral evergreen forests and maquis:	
		dominates the succession of *Juniperus oxycedrus*	1.24
		dominates the succession of *Juniperus oxycedrus, Pinus halepensis*	16.05
		dominates the succession of *Quercus ilex, Erica arborea, Juniperus oxycedrus*	10.89
		dominates the succession of *Quercus ilex, Juniperus oxycedrus*	8.47
		dominates the succession of *Quercus ilex, Juniperus oxycedrus* / affected by fire	2.13
		dominates the succession of *Quercus ilex, Pinus halepensis, Erica arborea, Juniperus oxycedrus*	32.36
		dominates the succession of *Quercus ilex, Pinus halepensis, Pinus nigra, Juniperus oxycedrus*	41.53
E.9.		Anthropogenic forest stands	24.36
E.9.2.		Stands with conifers: *Pinus halepensis, Pinus nigra, Pinus pinea*	7.86
E.9.2.4.		Stands with *Pinus halepensis*	52.20
F.		**Seaside**	**45.57**
F.3.1.1.		*Euphorbion peplis* R. Tx. 1950 **Characteristic species:** *Euphorbia peplis, E. pinea, E. paralias, Glaucium flavum, Cakile maritima, Salsola kali*	7.39
F.4.1.1.	1240 Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.	Rock and cliffs of the Mediterranean coasts covered by endemic species of *Limonium* spp.	23.04

Table 1. Continued

NCH code	NATURA 2000 code	Description of habitat types with characteristic species	Surface (ha)
F.4.1.1.1.	1240	*Plantagini-Limonietum cancellati* Horvatić (1934) 1939 **Characteristic species:** *Limonium cancellatum, Plantago holosteum, Chaenorrhinum minus, Crithmum maritimum, Elymus elongatus, Reichardia picroides*	11.30
F.4.1.1.1.	1240	*Plantagini-Limonietum cancellati* Horvatić (1934) 1939 subas. *schoenetosum* Pavletić 1992 **Characteristic species:** *Limonium cancellatum, Schoenus nigricans, Dorycnium hirsutum,Crithmum maritimum, Plantago holosteum, Elymus elongatus, Reichardia picroides*	3.84
I.		**Ruderal vegetation**	**57.18**
I.1.3.1.1.		*Lolio-Plantaginetum commutatae* Horvatić (1934) 1963 **Characteristic species:** *Plantago coronopus, Lolium perenne, Catapodium marinum, Hordeum leporinum, Lophochloa cristata, Rumex pulcher, Poa annua, Lolium rigidum*	4.60
I.2.1.		Mosaics of cultivated surfaces	43.19
I.5.2.1.		Traditional olive groves	2.40
I.8.		Non-produced cultivated green surfaces	2.62
I.8.1.9.		Intensely crowded public areas	4.37
J.		**Industrial habitats**	**13.82**
J.4.4.2.		Surface for road traffic	7.79
J.4.4.5.		Other infrastructure areas: paths and roads	6.03
		Epilitoric habitat of critically endangered species: *Convolvulus lineatus* L. and *Anthemis tomentosa* L.	1.03

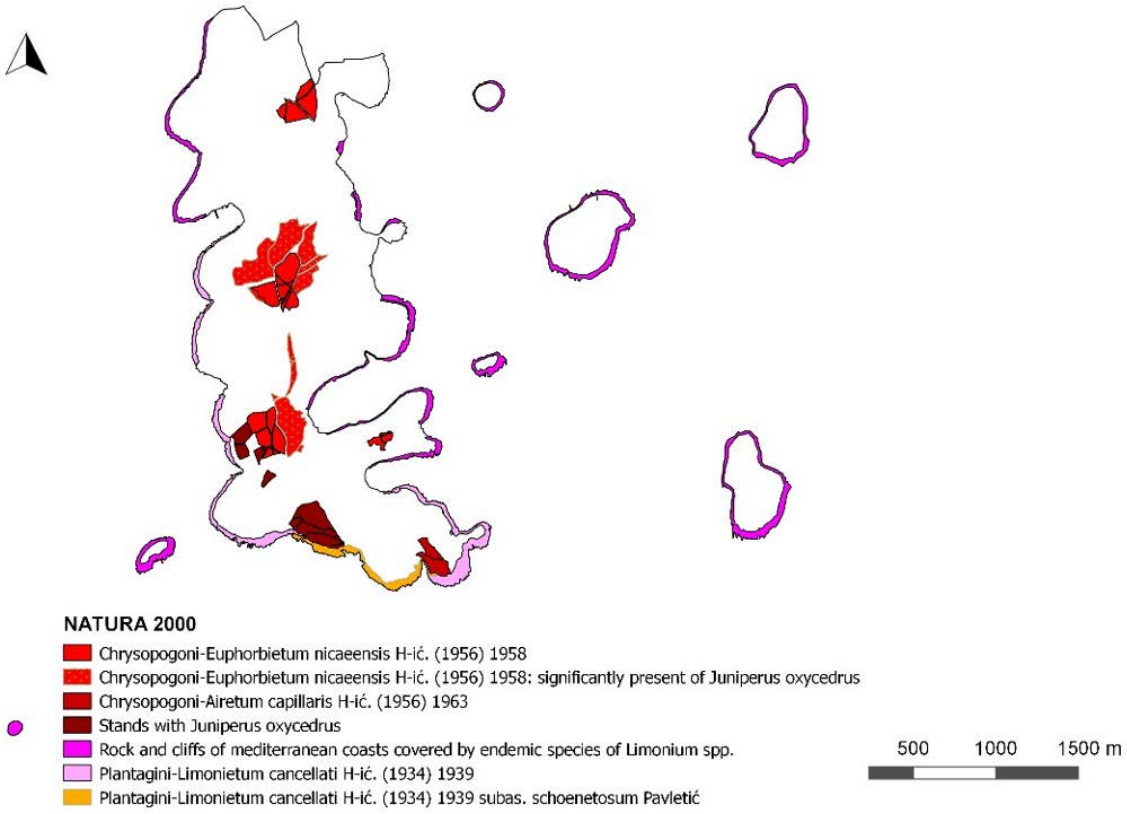

Figure 4. The distribution of Natura 2000 habitats of Protected Landscape of Donji Kamenjak and Medulin archipelago

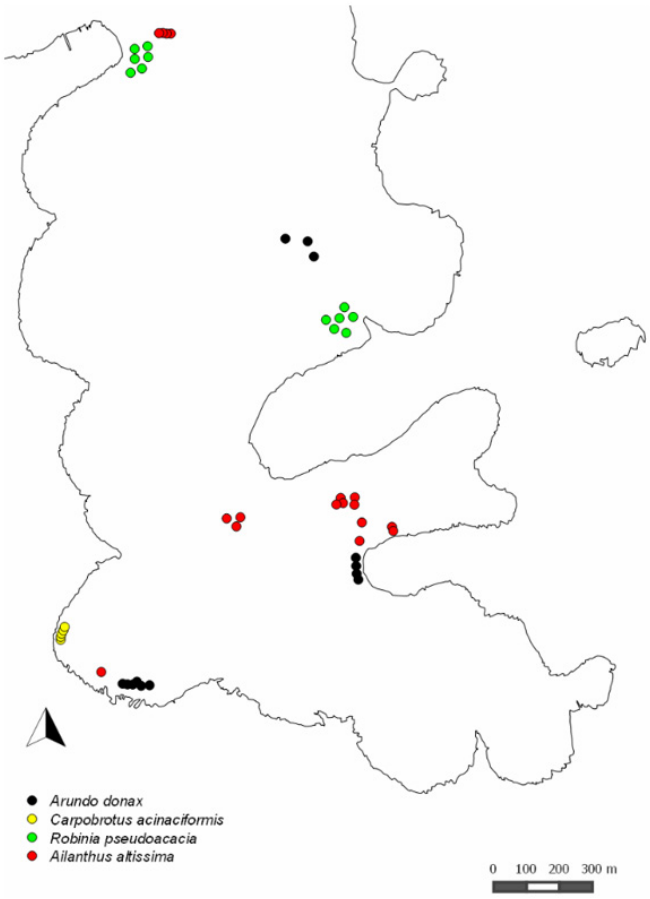

Figure 5. Distribution of naturalized and invasive woody plant species of Protected Landscape of Donji Kamenjak and Medulin archipelago

DISCUSSION

Natura 2000 is a European ecological network composed of areas important for the conservation of endangered species and habitat types of the European Union. Its goal is to preserve or re-establish the favorable status of endangered and rare species of both natural and semi-natural habitat types (Topić and Vukelić, 2009). On the researched area of PLDK it was found that only 18.78% of the territory belongs to Natura 2000 habitats, while the rest are mostly forests, maquis (about 197 ha) and cultivated areas (about 57 ha) with weed and ruderal vegetation.

Open habitat types such as eastern sub-mediteranean dry grasslands (*Chrysopogoni-Euphorbietum nicaeensis*) are suitable habitats for many orchids, and can be used as rocky pastures (Figure 6). Such pastures are habitats that substantially enrich plant and landscape diversity. However, in the area of PLDK, these are threatened habitats due to the abandonment of the traditional livestock breeding system. As an optimum for such grasslands it is recommended that the moderate sheep grazing intensity is one to two (animals/ha) or 0.1 livestock unit as suggested by Ljubičić et al. (2014). Such grazing intensity will contribute not only to the conservation of plant diversity, but also to the improvement of ecological sheep production and the sustainability of the habitat in the succession process. In recent decades, significant changes have occurred in these areas in terms of pasture use.

Namely, because of the development of tourism, sheep grazing was significantly abandoned and the number of sheep per unit area decreased drastically, leading to the succession process, in particular the spread of woody species *Juniperus oxycedrus* in the first stage (Figure 6).

Arborescent matorral with *Juniperus* spp. occupy the area on the southernmost part of PLDK, formed after grazing abandonment in the process of vegetation succession of eumediterranean and submediterranean meadows (Topić and Vukelić, 2009). The dominance of *Juniperus oxycedrus* woody shrubs gives the habitat a homogeneous appearance, although on the ground the floral composition may be significantly different depending on the climatic features. Such stands are developed as a succession stage during the succession of abandoned pastures and often remain as a permanent stage of vegetation for a long time (Topić and Vukelić, 2009). This habitat type is not endangered and does not need any additional protection measures besides the control of frequent fire.

Most of the surface has already been covered by shrubs and forests and it is more difficult to return them again to open habitats (Figure 6). In the last fifty years grasslands have been afforested with species of the genus *Pinus* spp. (mainly *Pinus halepensis* and *P. nigra*) for the purpose of tourism development. Therefore, it is necessary to preserve at least those pasture areas that have not been consumed to a great extent. In general, for all of the rocky pastures that build heliophilous plants, it is

necessary to provide open habitats and mainly by sheep grazing because there is no possibility of mowing on such habitats.

Figure 6. Successional stadium with woody species *Juniperus oxycedrus* on the grassland *Chrysopogoni-Euphorbietum nicaeensis* Horvatić (1956) 1958

Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea* (*Chrysopogoni-Airetum capillaris*) is dominated by *Chrysopogon gryllus* and *Aira elegantissima* species along with a series of terophytes that give the community a special characteristic feature. Since this community was originally described fifty years ago, today it has already adopted transitional forms. These are mainly open-thermomediterranean xerophilous low grasslands near the sea at PLDK which are suitable for sheep grazing, but because of a somewhat deeper soil they can be mowed. Given that they are no longer used, or are occasionally used today for grazing, such grasslands have been left to succession and developmnet of maquis. Unfortunately, losing such habitats decreases the plant diversity and the open landscapes of the eumediterranean area are lost. Maintenance of these habitats is possible by firefighting method but only on limited surfaces with strict control. Vegetated sea rocks and cliffs of the Mediterranean coasts are characterized by usually endemic *Limonium* species that are covered with halophilous vegetation of the *Crithmo-Limonietea* class. Within this group along the littoral rocky coasts of PLDK, plant communities of local character with the endemic *L. cancellatum* as a differential species occur, such as the halophytic community *Plantagini-Limonietum cancellati*. It is a costal open habitat type with only a few species, such as *Plantago holosteum*, *L. cancellatum*, *Crithmum maritimum*, *Reichardia maritima* etc. Within this plant community there is also a community of *Plantagini-Limonietum cancellati* subas. *schoenetosum* with domination of the species *Schoenus nigricans*. Special measures for the conservation of these habitats are not required except for the control of the partial destruction of the localities heavily visited by tourists.

Therefore, the problem occurs with habitat types of a transitional character and less strict syntaxonomic position. However, these are indeed habitats, and should be accepted as such. These are often different stages in the succession of vegetation or transitional communities in places where geographically or ecologically two or more plant communities are in symparty (Trinajstić, 2008; Vukelić et al., 2008; Topić and Vukelić, 2009).

On the rocky pastures that occupy most of the PLDK, where the possibility of mowing for economic reasons is unprofitable, it is advisable to perform moderate grazing with indigenous sheep breeds which contributes to the conservation of plant diversity and habitats but also to the development of ecological sheep production. The livestock selects and carries on the pasture only the favourable herbs, leaving out poisonous, prickly or stingy plants which then rapidly expand (Horvat, 1949). However, intense grazing disables the development of plant growth and leads to major changes which can result in complete destruction of the plant communities (Horvat, 1949; Puerto et al., 1990; Montalvo et al., 1993). Moderate grazing pressure favors plant diversity and direct consumption of dominant species, which indirectly affects the competition of plant species and encourages plant coexistence (Grime, 1973; Al-Mufti et al., 1977).

Mechanically removing undesirable species should be applied to woody species (*Juniperus oxycedrus*, *Erica arborea*, *Ailanthus altissima* and others) when they grow sporadically on the pastures. The cuttings of such species should be applied as soon as possible because in the later phase of succession and the development of dense

maquis, the process is much more difficult and longer lasting. In addition, it is necessary to mechanically remove alien and invasive plant species of PLDK. Allochthonous species can be expected in habitats under higher anthropogenic influences, along the road and road edges (Mitić et al., 2008). For now, none of the established allochthonous species has been recorded on larger surfaces and with large population density. Nevertheless, the species *A. altissima* can be expected to grow faster because it is an extremely opportunistic, adaptable and aggressive species that suppresses the autochthonous taxa in its vicinity and thus reduces the biodiversity and value of natural ecosystems (Novak and Kravarščan, 2013). Burning method is also effective in eliminating unwanted vegetation of maquis created in the process of progressive succession. As suggested by Kowarik and Säumel (2007), *A. altissima* needs to be chemicaly treated. It is a positive thing to quickly eliminate unwanted vegetation and open a habitat for new species, while the negative side is a radical degradation of biodiversity, and furthermore, fires can only be carried out on limited surfaces. The naturalized species *Arundo donax* (Figure 5) is also very dangerous in PLDK. This species is used in the construction of walls and roof of the 'Safari Bar' on Rt Kamenjak, which is a very creative practice, but spreading of that species is worrying. Currently, the species *Arundo donax* is not prohibitive and not much represented (Figure 5). If it occupies a larger area, the rhizomes of *A. donax* plant species should be mechanically removed from the ground.

CONCLUSION

The habitats of Protected Landscape of Donji Kamenjak are rather diverse whereas many habitat types were identified in a relatively small area.

There is significant coverage of Natura 2000 habitats, which should be protected and conserved.

Such habitats significantly increase plant and landscape diversity; owever, they are endangered due to frequent overloading of cattle or else abandonment of traditional style sheep farming. Vegetation success is the main threat to habitat diversity.

Given all the above, sheep grazing of moderate intensity is the most efficient method of preserving the threatened habitats, and is highly recommended on the PLDK.

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