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"Effects of recreational trampling in Mediterranean shrub *Globularia alypum* L."

TREBALL FINAL DE GRAU

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ABSTRACT

Trampling is one of the most visible forms of disturbance to vegetation as a result of recreational use resulting in loss of vegetation height and cover and changes in plant community composition.

In order to identify and quantify such impacts, in this thesis a study on Capo Sant'Elia, a calcareous promontory located within the municipality of Cagliari (southern Sardinia) has been carried out. Effects of trampling on Mediterranean shrub *Globularia alypum* were evaluated realizing transects located a different distance to the paths. Moreover, the population size of *G. alypum* in Capo Sant'Elia was quantified by a census, and the estimation of visitors' number, (hikers and cyclists) that frequented this area, was done.

The results of this thesis show that effects of trampling on *G. alypum* are limited to paths, and not outside them, and are caused by the high amount of visitors (due to the proximity to the city), which have a peak on Sundays.

The management actions that we propose on the basis of the results obtained are the control and removal of invasive species (*Acacia saligna*) detected in the study area and the implementation of educational activities on maximum-influx days for raise awareness through the population about naturalness conservation.

Keywords: *Globularia alypum*, Mediterranean shrubland, recreational area, Sardinia, trampling.

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1. INTRODUCTION

Mediterranean coastal habitats have been altered by human activity for several thousand years, and coastal environments are strongly affected by tourism and by the related infrastructures needed (Davenport and Davenport, 2006), as well as by the increasing of nature-based tourism and recreational demand, including in protected natural areas (Pickering and Hill, 2007), some of whose are located in coastal areas.

Among the coastal areas, the capes, because of their geo-morphological characteristics, being open towards the sea and exposed to the winds, are usually unaffected by urban and/or tourist developments, which are commonly located in adjacent coastal areas or in the hinterland; nevertheless these territories favour the conservation of ecosystems of naturalistic interest with a high degree of biodiversity (Bocchieri and Iiriti, 2009).

It is generally recognised that increased tourism and recreational use results in increased damage in coastal areas, in particular this entailed negative environmental impacts on water, soil, animals, plants and vegetation (Myers *et al*., 2000; Van der Duim and Caalders, 2002; Butchart *et al*., 2010; Steven *et al.*, 2011).

Most obvious impacts on vegetation from popular nature-based activities, such as hiking and mountain biking, include vegetation being crushed, sheared off and uprooted. These impacts also can result in loss of height, biomass, reproductive structures, and reduction in cover, increased litter, and damages to seedlings and changes in species composition (Pickering and Hill, 2007). As a result of these impacts, sensitive species and plant communities may decline while resistant species such as weeds are able to dominate modified ecosystems (Cole, 2004; Pickering and Hill, 2007; Hamberg *et al*., 2008; Pickering *et al.*, 2010; Monz *et al*., 2010).

Anyway, the damage of the vegetation from recreation activities and tourism will be influenced according the type of infrastructures provided, the type of activities, the season of use and the behaviour of visitors (Pickering and Hill, 2007).

In addition tourism and recreation activities can contribute to habitat fragmentation with the internal fragmentation of remaining vegetation by trail networks done (Pickering *et al*., 2012).

Despite such well recognised environmental impacts, few studies have focused on the effects of tourism, recreation and the impacts of human trampling on Mediterranean coastal ecosystems (Comor *et al*., 2008; Kutiel, Eden, and Zhevelev, 2000; Kerbiriou *et al.*, 2008) most of whose related to threatened plants (Peñas *et al*., 2011; Fenu *et al*., 2013).

Moreover, human trampling, that often affects ecosystems of high conservation value (Andrés-Abellán *et al*., 2006; Bowles and Maun, 1982), is an integral part of the problems of conservation management of natural areas (Gallet and Rozé, 2001, 2002; Kutiel *et al*., 1999; Rossi *et al*., 2009).

In Mediterranean coastal ecosystems some plant species (including threatened plants) are very sensitive to trampling, while others seem to be tolerant or even to benefit from trampling (Kerbiriou *et al*., 2008; Yu, Bell, and Kutiel, 2009; Fenu *et al*., 2013). Has been demonstrated that human trampling is currently an important threat for plant species in Sardinia (Quilichini and Debussche, 2000; Fenu, Mattana, and Bacchetta, 2011; Fenu *et al*., 2013; Rossi *et al*., 2015).

Accordingly, the aims of this thesis are: (1) to know the population size of the phytogeographic interesting species *Globularia alypum* located in natural coastal area of Capo Sant'Elia (southern Sardinia); (2) to evaluate the effects of human trampling on Capo Sant'Elia (and in particular on *G. alypum*) in order to suggest management recommendations for the conservation of this natural area.

1.1 Study area

1.1.1 Geological and geographical context of study area

Sardinia is situated in the western Mediterranean basin (38° 51' and 41° 15' latitude north, 8° 8' and 9° 50' east longitude), covering ca. 24,090 km^2, and the maximum altitude reaching 1,834 m.a.s.l. (Punta La Marmora, Gennargentu Massif, CE-Sardinia).

The study area, located in the southern Sardinia, is Capo Sant'Elia promontory (Capo S. Elia hereafter; Figure 1), within the municipality of Cagliari (39° 11' latitude north, 9° 10' east longitude), with an area of 200 ha and a maximum height of 136 m.a.s.l. The small pebble beach named "Calamosca" (Figure 2) separates the area in two parts: the eastern zone, with the highest height, from the western one, lower height (94 m.a.s.l.) called "Colle Sant'Ignazio".

Figure 1. Map of the study area "Capo S. Elia" (images A and B from: http://www.d-maps.com/; image C from: Google, TerraMetrics).

Figure 2. View of "Capo S. Elia". In the centre the "Colle Sant'Ignazio" behind the "Calamosca" pebble beach (photo from: http://www.sardegnadigitallibrary.it/).

Capo S. Elia represents the only presence of calcareous rocks in the southeast Sardinia (Biondi and Mossa, 1992).

Geologically in Capo S. Elia, as well as in all promontories of Cagliari, emerges the upper part of the Miocene series, constituted by the Tortonian-Messinian transgressive-regressive succession (Figure 3). The transgressive phase is occurred during Tortonian age, in which calcareous and clayey sediments of the external platform are deposited, in the regressive phase it is built a bio-constructed carbonate platforms (Kalb, 2008).

This calcareous succession is formed by the following stages, from the bottom to the top:

- “Arenarie di Pirri”: consisting mainly on quartz (70%);
- "Pietra Cantone": clayey-sandy calcareous layer;
- The biohermal layers of "Pietra Forte".

“Arenarie di Pirri”, is layer dated from the Serravallian period (Miocene). With grey-yellow colour, is constituted by quartz (minimum 70%), feldspar and mica (30%). The average thickness of this layer in Capo S. Elia is about 70-80 m.

“Pietra Cantone” layer is characterized by clayey-sandy calcareous rocks, whose colour varies according to the amount of sand and clay. Its maximum thickness in Capo S. Elia is 50-60 m.

Finally, “Pietra Forte*”* is layer composed by compact biological calcareous material, white- grey, also known as “*Lithothamnium calcarea*”. It represents the most recent phase of the tertiary marine succession in southern Sardinia (Biondi and Mossa, 1992).

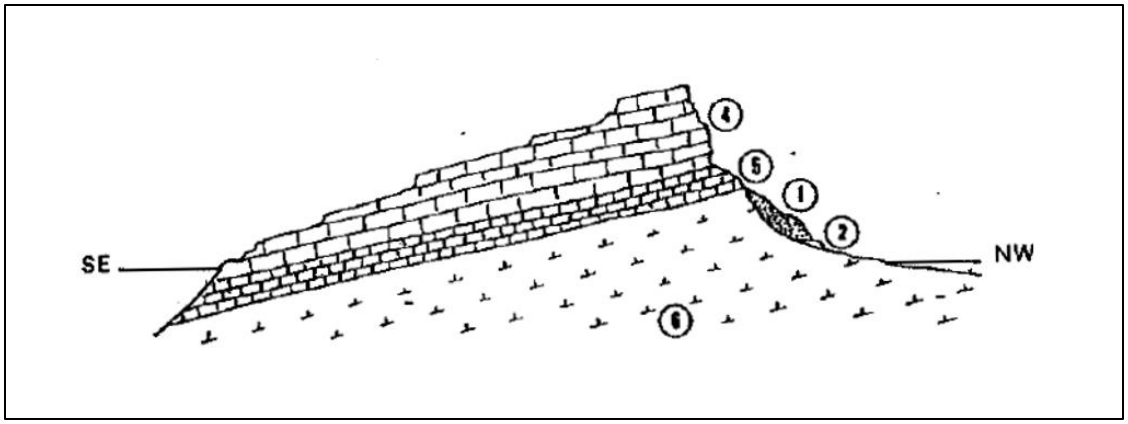


Figure 3. Lithological profile of “Capo S. Elia”: 1. Aeolian sand; 2. Beach conglomerate; 4. “Pietra Forte”; 5. “Pietra Cantone”; 6. “Arenarie di Pirri” (Biondi and Mossa, 1992).

1.1.2 Climate context of study area

Sardinia has a two-seasoned climate, with one mild and humid season from autumn to spring months, and another hot and dry season during summer period (Bacchetta *et al.*, 2009).

The bioclimatic analysis of the study area was carried out using thermo-pluviometric data recorded by the nearest weather station (Cagliari) in the period 1974-2003 (Table 1; Figure 4; De Martis, 2008).

Table 1. Climate data from the Cagliari weather station for the period 1974-2003. Abbreviations: T med=Temperatures medium; T max= Temperatures maximum; T min=T minimum; P=precipitations.

	T med (ºC)	T max (ºC)	T min (ºC)	P (mm)
Jan	11.2	14.8	7.5	36.3
Feb	11.6	15.4	7.7	48.2
Mar	13.1	17.3	9.0	34.1
Apr	14.9	19.0	10.7	39.9
May	18.7	23.2	14.2	25.3
Jun	22.7	27.5	18.0	10.6
Jul	25.6	30.4	20.8	4.1
Aug	26.0	30.6	21.3	9.1
Sep	23.1	27.4	18.9	27.0
Oct	19.7	23.7	15.7	51.2
Nov	15.3	19.1	11.5	57.1
Dec	12.3	16.1	8.5	51.1
Annual	14.9	22.0	13.7	394.0

The mean annual temperature and the annual precipitation of the Cagliari station are the following: 17.9°C and 394.0 mm.

This data allowed to classify the study area, according to bio-climatic classification of the land proposed by Rivas Martínez (1981), as Mediterranean Pluviseasonal Oceanic (MPO), according with the thermicity index ($I_{(t)}$ = 385), which is upper thermomediterranean thermotype, and the summer ombrotype index (*Iov* = 0.3), which is upper dry ombrotype (De Martis, 2008).

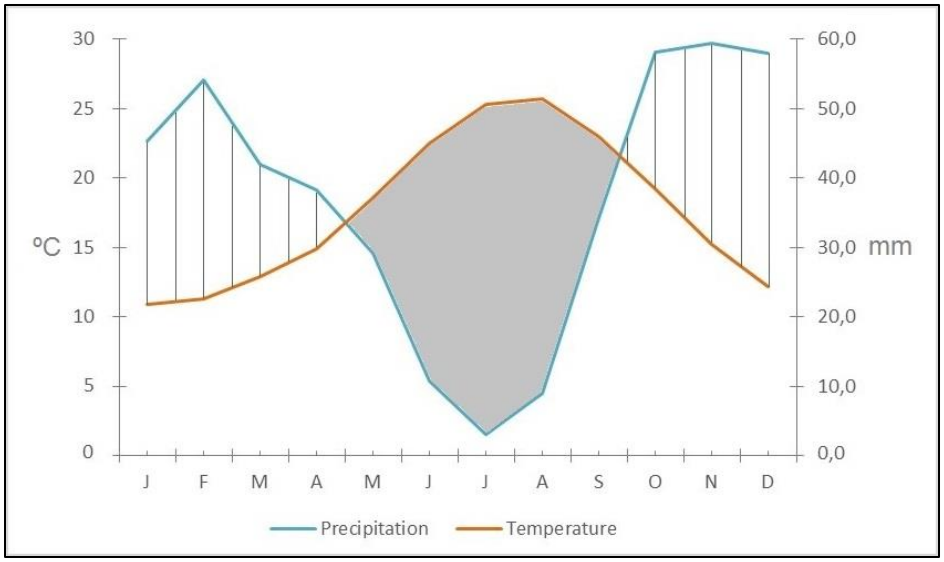


Figure 4. Climatic diagram of Cagliari weather station.

1.1.3 Vegetation-floristic characterization of the study area

From the floristic point of view Capo S. Elia presents a high species richness (547 *taxa*; Bocchieri and Ilriti, 2005). In Capo S. Elia there is a significant presence of endemic flora, with 19 endemisms, 7 of which Sardinian exclusive endemics, and specifically *Bellium crassifolium* Moris, *Helichrysum microphyllum* (Willd.) Camb. ssp. *tyrrhenicum* Bacch., Brullo & Giusto, *Limonium capitis-eliae* Erben, *Limonium retirameum* Greuter & Burdet ssp. *caralitanum* (Erben) Arrigoni, *Limonium retirameum* Greuter & Burdet ssp. *retirameum*, *Orobanche denudata* Moris, and *Delphinium longipes* Moris (Bocchieri and Ilriti, 2009).

Capo S. Elia, as other capes and promontories in Sardinia, apart from being marked by an important endemic floristic component, also is the habitat of rare species of considerable phytogeographical importance as *Sarcopoterium spinosum* (L.) Spach and *Globularia alypum* L. populations (Bocchieri and Iiriti, 2009).

The vegetation of the study area have been classified depending on the geomorphologic aspects and the substrate type (Figure 5; Biondi and Mossa, 1992). Specifically, on compact calcareous rocks of "Pietra Forte" and "Pietra Cantone" grows the juniper calcareous series. This series is characterized by maquis referable to the associations *Oleo-Juniperetum turbinatae* Arrigoni, Bruno, De Marco & Veri *in* De Marco Dinelli & Caneva 1985 *corr*. Biondi and Mossa 1992 (where is present *G. alypum*) and *Asparago albi-Euphorbietum dendroidis* Biondi and Mossa 1992; garrigues pioneer with *Genisto corsicae-Sarcopoterietum spinosi* Biondi and Mossa 1992 and *Thymelaeo hirsutae-Thymetum capitati* Biondi and Mossa 1992*;* from discontinued perennial grasslands with *Asphodelo microcarpi-Brachypodietum retusi*

Biondi and Mossa 1992 and terophytic formations with *Sedetum caerulei* Brullo 1975; *Lophochloo cristatae-Plantaginetum lagopi* Biondi and Mossa 1992, *Aveno sterilis-stipetum capensis* Biondi and Mossa 1992 (Biondi and Mossa, 1992; Bacchetta *et al*., 2007).

On limestones debris with clay soil it is found the series of *Anagyris foetida*, maquis vegetation characterized by *Euphorbio dendroidis-Anagyridetum foetidae* Biondi and Mossa 1992, and grasslands with *Ampelodesmos mauritanicus* (*Cistus incani-Ampelodesmetum mauritanici* Biondi and Mossa 1992; Biondi and Mossa, 1992).

Finally, on "Arenarie di Pirri" layer is present the siliceous series of *Lygeum spartum*, characterized by perennial grasslands related association *Phagnalon annotici-Lygeum sparti* Biondi and Mossa 1992 (Biondi and Mossa, 1992).

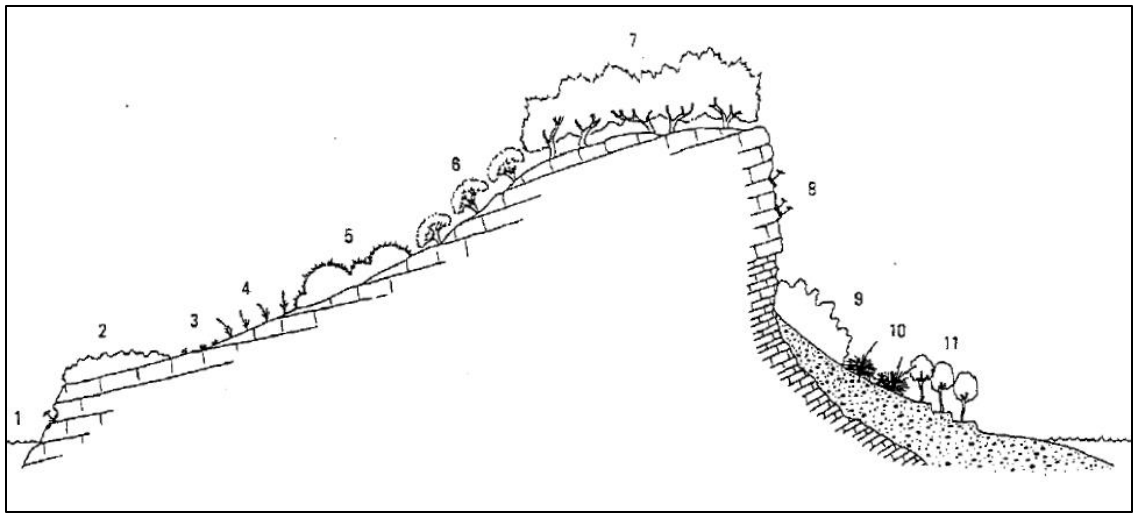


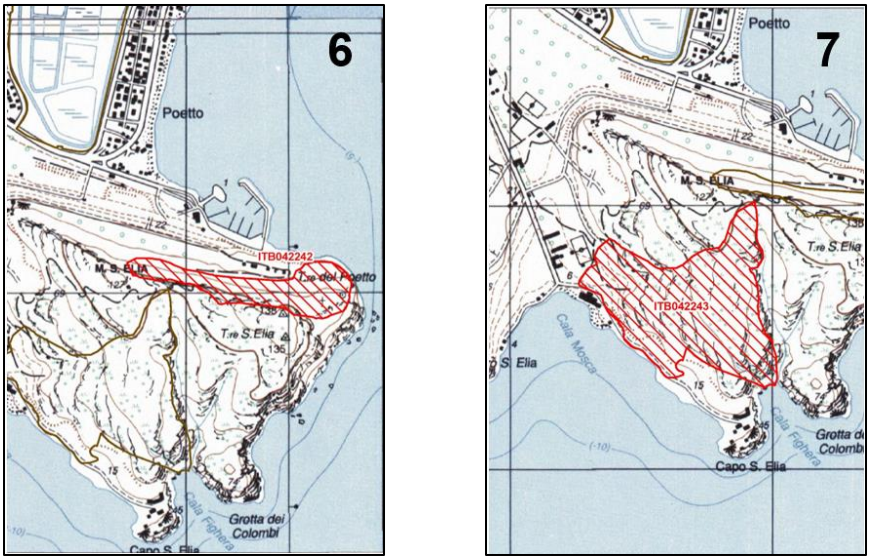
Figure 5. Transect of "Capo S. Elia" vegetation, South-North direction. 1: *Crithmo-Limonietum retiramei*; 2: *Salsolo vermiculatae-Atriplecetum halimi*; 3: *Lophocloo cristatae-Plantagenatum lagopi* and *Valantio muralis-Sedetum caerulei*; 4: *Asphodelo microcarpi-Brachypodietum ramosi*; 5: *Genisto corsicae-Sarcopoterietum spinosi;* 6: *Asparago albi-Euphorbietum dendroidis*; 7: *Oleo-Juniperetum turbinatae*; 8: *Crithmo-Limonietum retiramei* subass. *bellietosum crassifolii*; 9: *Euphorbio dendroidis-Anagyridetum phoetidae*; 10: *Cisto incani-Ampelodesmetum mauritanici*; 11: Abandoned olive tree field (Biondi and Mossa, 1992).

1.1.4 Threats and conservation

The study area comprises two SCI (Sites of Community Importance) form the Natura 2000 network:

- "Torre del Poetto" (ITB 042242; Figure 6), extends over an area of ca. nine ha, is located in the northern slope of Capo S. Elia. Within this SCI is present the habitat "Thermo-Mediterranean and pre-desert scrub" (code 5330) listed in the Annex I of European Union Habitats Directive 92/43/EEC;

• “Monte Sant’Elia, Cala Mosca e Cala Fighera” (ITB 042243; Figure 7), which extends over an area of ca. 27 ha, includes six habitats (1430, 5210, 5330, 5430, 9540) among which the priority habitat "Pseudo-steppe with grasses and annuals (*Thero-Brachypodietea*)" (code 6220*).



Figures 6-7. Maps of SCI “Torre del Poetto” ITB042242 (left) and “Monte Sant’Elia, Cala Mosca e Cala Fighera” ITB042243 (right; images from: http://www.minambiente.it/).

2. MATERIAL AND METHODS

2.1 Study species

The genus *Globularia* L. includes about 34 species and subspecies (The Plant List 2013), that grow in dry places such as mountain rocks, grassland or stony slopes, in all Europe (Tutin, 1972) and the rest of Mediterranean Basin (De Bolòs, 1995) which includes north of Africa and Middle Eastern countries.

In Italy eight species of *Globularia* genus are present: 1) *G. punctata* Lapeyr., in the most of Italian continental regions; 2) *G. cordifolia* L. and 3) *G. nudicaulis* L., both in the northern Italy; 4) *G. meridionalis* (Podp.) O. Schwarz, in southern continental Italy; 5) *G. incanescens* Viv. in Tuscany region; 6) *G. repens* Lam., in Piemonte and Liguria regions; 7) *G. neapolitana* O. Schwarz, in Campania region and 8) *G. alypum* L. (Pignatti, 1982).

The study species, *Globularia alypum*, is a nanophanerophyte shrub (Figures 8-9) from the *Globulariaceae* family, which can reach 0.8 m high. It has perennial sclerophyllous leaves with an alternated and scattered arrangement. The flower-heads are composite, in the form of a pseudanthium with 10-15 mm diameter, consisting of many sessile flowers with a characteristic blue-purple corolla (Figures 10-13). The flowering starts in October and ends in March (Pignatti, 1982).

Figures 8-9. Shrubs of *G. alypum*.

Figures 10-13. Detail of *G. alypum* flowers.

Early and late flowering of *G. alypum* allows the persistence and survival of natural populations; under stress by low temperatures, late flowering of the *taxon* is favored (Estiarte *et al.,* 2011). However, there is a lack of available information about reproduction and seed dispersion of *G. alypum*.

G. alypum is a resprouter shrub, distributed in dry calcareous and rocky places in the Mediterranean Basin (Prieto *et al.,* 2008), from North Africa (Morocco, Algeria, Tunisia) to South of Europe (Spain, France, South of Italy, Greece, Albania and ex-Jugoslavia (Tutin, 1972) also including Turkey, Lebanon and Palestine (Martinoli, 1950).

In Italy, *G. alypum* is distributed from sea level to 600 m.a.s.l. in western Liguria and Tuscany regions. The species is also present in Sicily and Sardinia, as well as in Elba, Egadi and Lampedusa islands (Figure 14; Pignatti, 1982).

Specifically, in Sardinia, *G. alypum* is present exclusively in Cagliari municipality (Capo S. Elia promontory) where was indicated for the first time in the 1827 by Moris (Figure 15, Martinoli, 1950).

The figures which appear in this thesis without references belong to the author.

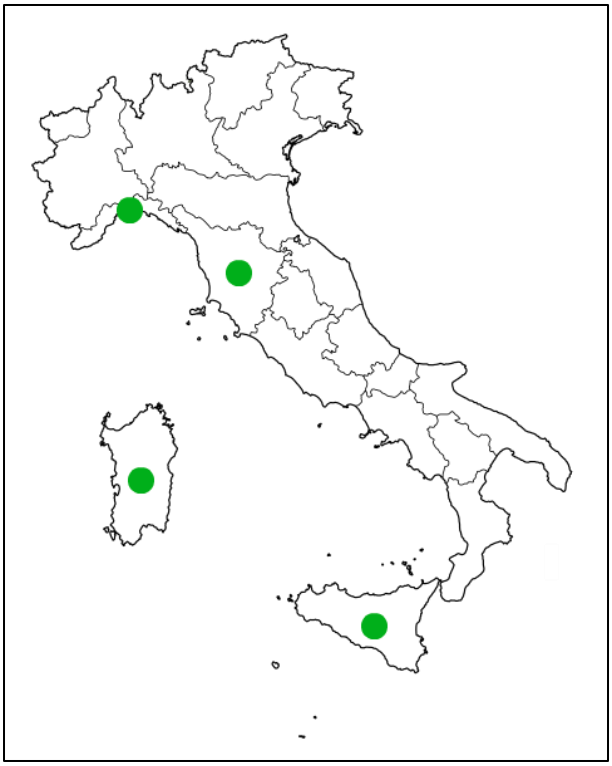


Figure 14. Distribution regions of *G. alypum* in Italy (modified image from: Wikimedia Commons).

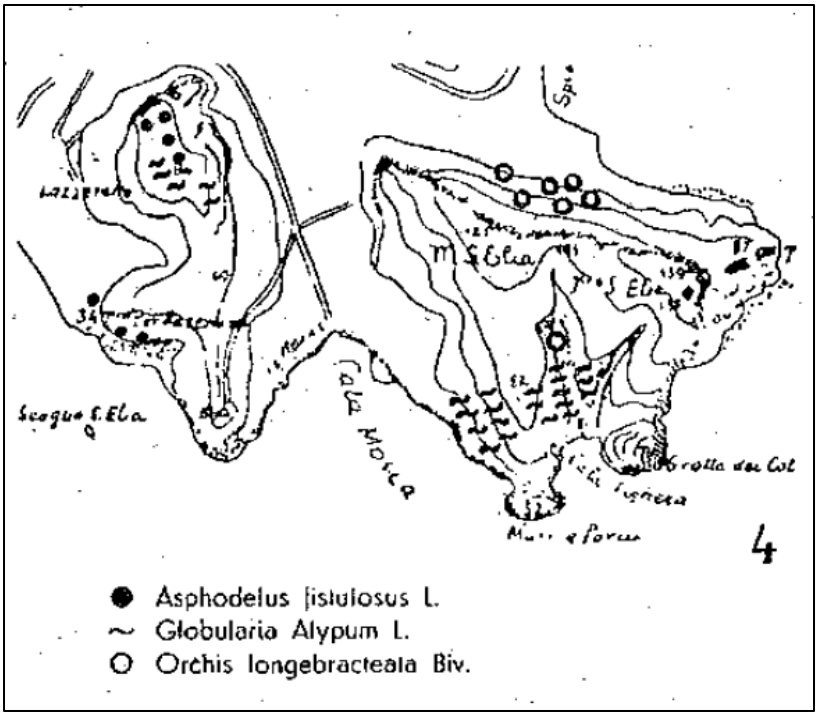


Figure 15. Distribution of *G. alypum* in "Capo S. Elia" (Martinoli, 1950)

2.2 Field work: Effects of visitor on study area

In order to determine the effects of visitors on study area, it was made a counting of all visitors in the period in which the area is frequented for recreational use, January-June 2016. To evaluate the visitors' affluence at seasonal level, the counting was carried out each three months: in January, March, and June.

Specifically, all visitors that ran through two different paths: the access path (hereafter "first path") and the path to the exit (hereafter "second path"; Figure 16), were counted from 8:00 to 17:00 hours. The counting was carried out during days of maximum and minimum influx of visitors, respectively Sunday and Monday. On the basis of observation in field, to discriminate the different kind of fruition, the visitors were classified into two groups: cyclists and hikers.

Figure 16. Position of first (yellow) and second (orange) paths (modified image from: Google, TerraMetrics).

2.3 Field work: Effect of trampling on vegetation

Along the two selected paths (see above), in the trampled area crossed by the footpath, two transects (100 m long) were placed (hereafter "T1" and "T2" for the transects done in the first path and second path, respectively, Figure 17). Along the transects, each 5 meters were established and monitored five parallel plots (2 x 1 m), one at the centre of transect (Figure 18) along the path, two plots at distance of 2 m and 5 m, both to the left and the right of the path (Figure 19), for a total of 210 plots.

Figure 17. Location of the transects in the study area, T1 situated at the beginning of the first path, and T2 in the middle of the second one (modified image from: Google, TerraMetrics).

Figure 18. Field work, effect of vegetation trampling: plot (2 x 1 m) along the first path.

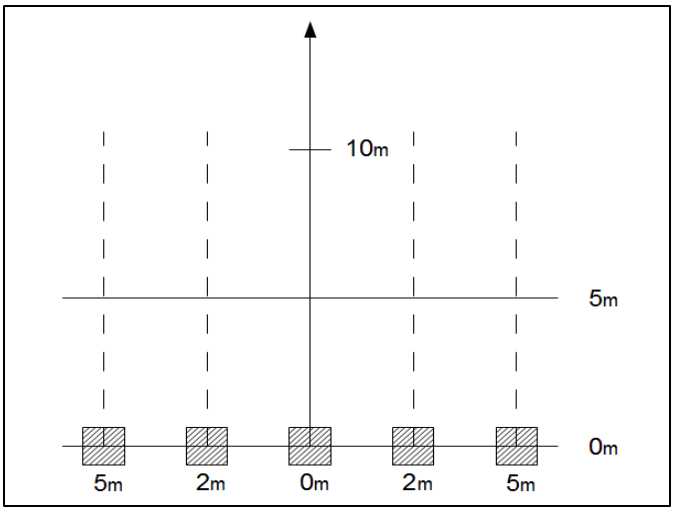


Figure 19. Diagram showing the position of plots in the transect.

Within the plots, the average height of the vegetation (cm) were measured and the cover was visually estimated (%). All individuals of *G. alypum* inside the plots were also counted, their height were measured and the percentage of flowers and fruits of each plants were calculated.

2.4 Field work: *Globularia alypum* census

To estimate the consistency of *G. alypum* population in the Capo S. Elia station, all individuals of the species, present in 2 sub-areas (Figure 20), were marked by aluminium labels and counted. This counting was carried out from March to May 2016, the period that coincide with the peak of flowering.

All graphs and data analysis were carried out using the package software Excel.

Figure 20. Map of the two sub-areas (A-B) where *G. alypum* is located. In yellow and orange first path and second path respectively (modified image from: Google, TerraMetrics).

3. RESULTS

3.1 Effects of visitors on study area

During the six days (45 hours) of the visitors' monitoring, a total of 2,254 visitors were counted. Of total visitors, the hikers were the most (1,942; 86.2%), while the cyclists were 312 (13.8%).

Analysing the frequency at seasonal level (Table 2; Figure 21), the summer was the season in which the highest number of visitors was recorded (982 in total; 873 hikers, 109 cyclists), followed by the spring (853 in total; 762 hikers, 91 cyclists), and the winter (419 in total; 307 hikers, 112 cyclists).

Table 1. Results obtained from the visitor counting. Data are divided by seasons, day and type of fruition.

	Winter	Spring	Summer	Total
Hikers				
Sunday	279	700	813	1,792
Monday	28	62	60	150
Total	307	762	873	1,942
Cyclists				
Sunday	93	78	91	262
Monday	19	13	18	50
Total	112	91	109	312
Total Hikers + Cyclists	419	853	982	2,254

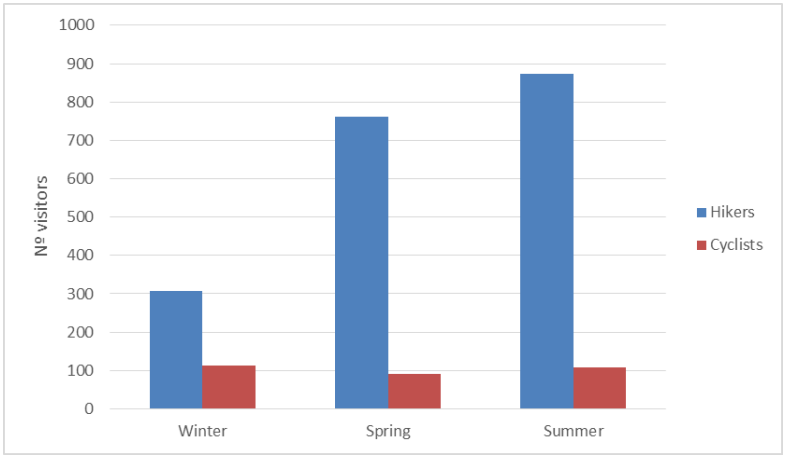


Figure 21. Number of visitors separated by activities, per each season.

Sunday it is confirmed the day of maximum affluence, with a total of 904 visitors (both hikers and cyclists) in summer, 778 visitors in spring, and 372 visitors in winter. Conversely, the lowest affluence was recorded on Monday, with a total of 78 visitors on summer, 75 in spring, and 47 in winter.

3.2 Effect of trampling on vegetation

The results of the parameters recorded within the plots highlighted that in the centre of paths the coverage of plants was almost completely absent (2.9±9.1% mean of both transects); while the coverage increases at distance of two and five meters far from the transects, where the average cover is respectively 57.4±25.5% and 53.4±24.9% (Figure 22).

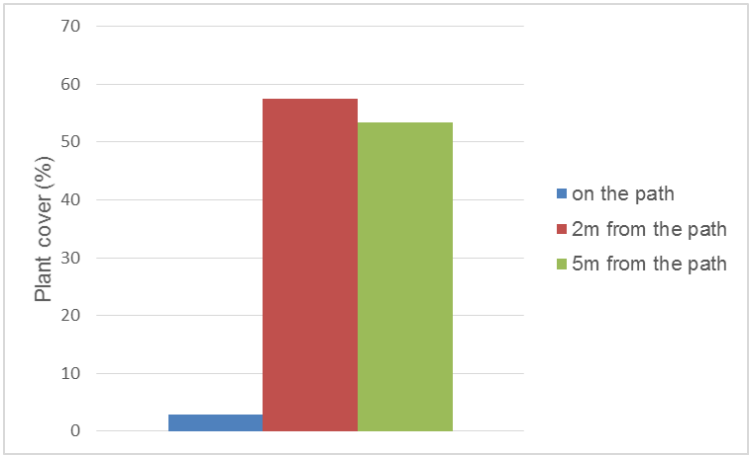
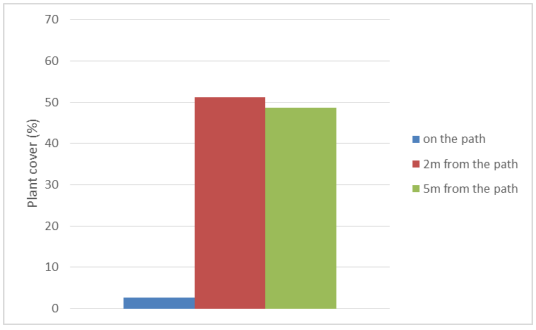
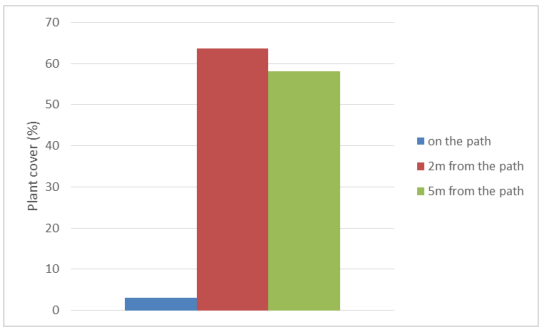


Figure 22. Average percentage of plant cover measured in both transects, in the centre of the transect, and two and five meters in the sides of the transect.

Among the transects there are differences in the coverage values (Figures 23-24). In fact, the T1 has percentages of coverage lower (51.2±24.3%, 48.7±26.0%; respectively at two and five meters) than T2 (63.7±25.8%, 58.1±23.3%; respectively at two and five meters).





Figures 23-24. Percentage of plant cover: in T1 (left graph) and T2 (right graph), in the centre of the transect, and two and five meters in the sides of the transect.

Regarding the results of vegetation height, the total average height was 4.1±11.8 cm for plots made in the centre, while the height increases at distance of two and five meters far from the transects, where the height is respectively 58.3±25.8 cm and 59.1±23.8 cm (Figure 25).

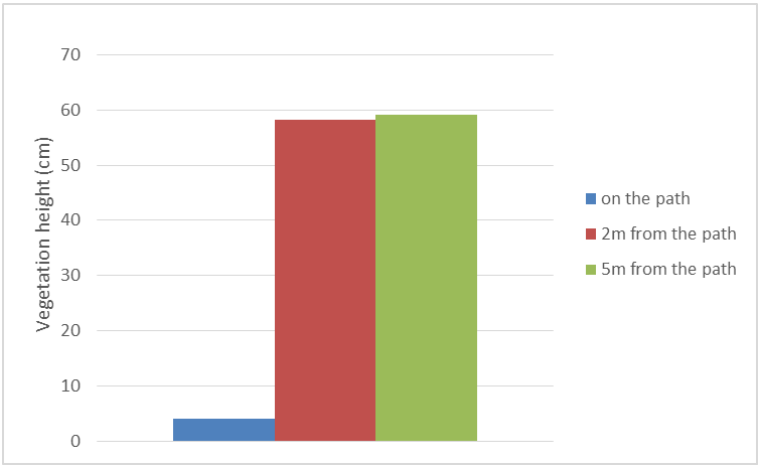
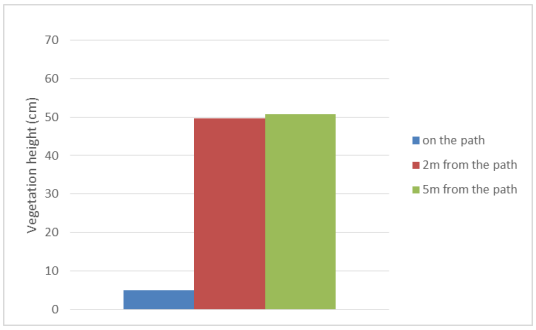
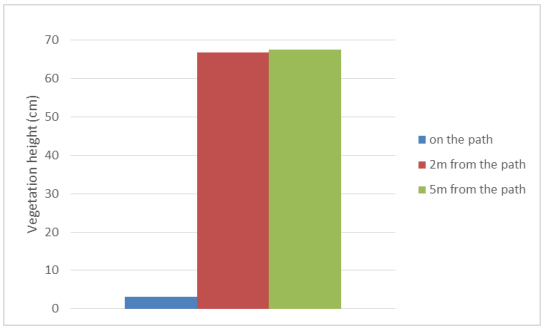


Figure 25. Average of vegetation height in plots of both transects measured in the centre of the transect, and two and five meters in the sides of the transect.

Among the transects there are differences in the height values (Figures 26-27). The T1 has the average height vegetation lower (49.7±20.3 cm, 50.7±21.9 cm; respectively at two and five meters) than T2 (66.8±28.2 cm, 67.6±23.0 cm; respectively at two and five meters).





Figures 26-27. Vegetation height in T1 (left graph) and T2 (right graph), measured in the centre of the transect, and two and five meters in the sides of the transect.

Regarding effects of trampling on the study species, *G. alypum* was found exclusively in the second transect. A total of 76 individuals of *G. alypum* were found in the plots from the 35 m until the end of the transect (100 meters).

Regarding the percentage of fruiting of *G. alypum* (Figure 28), in the plots of the centre of the T2 only one individual of *G. alypum* was detected (85% of fruiting and a height of 31 cm), while at two meters the fruiting average is equal to 56.2±30.6% and at five meters is equal to 56.9±30.2%.

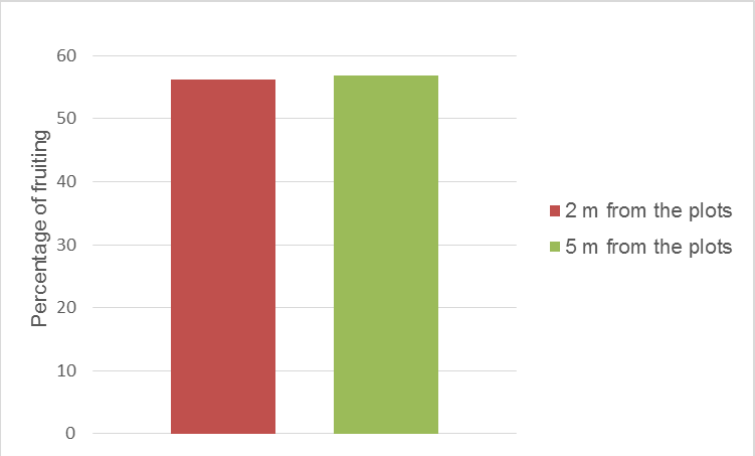


Figure 28. Average percentage of fruiting for the plants of *G. alypum* in T2.

Regarding to the results of *G. alypum* height (Figure 29), the average height was 28.2±12.5 cm and 28.3±12.8 cm respectively at distance of two and five meters.

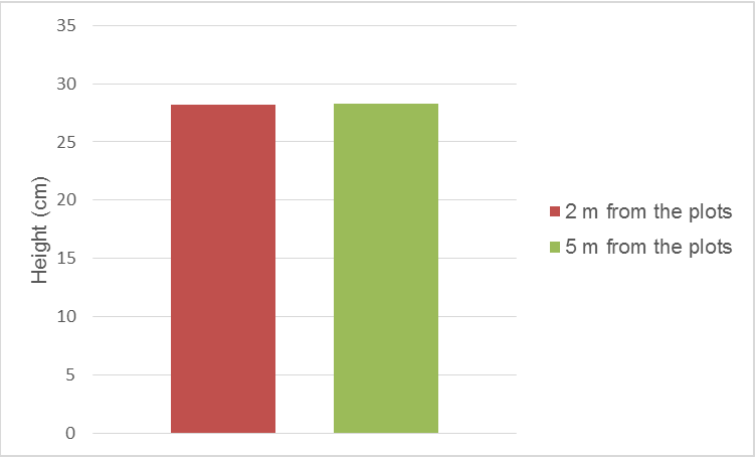


Figure 29. Average height for the plants of *G. alypum* in T2.

The total number of *G. alypum* plants in the T2 at distance of two meters was upper (39 plants), than those detected at five meters (36 plants).

Finally, we verified that there is no correlation between the parameters fruiting and height in individuals of *G. alypum* (R^2 = 0.0057)

3.3 *Globularia alypum* census

A total of 4,000 plants of *G. alypum* were counted in the study area within a surface equal to 14,299 m^2. The population is divided in 2 sub-areas (sub-area A: 9,187 m^2; sub-area B: 5,112 m^2; see Figure 20). Of 4,000 plants of *G. alypum* censed, only 51 not were flowered (1.3% of total).

It has been impossible to carry out a counting total of the population because of inaccessibility of the some areas where the plant grows; we estimated that the population of Cagliari is consisted of about 7,860 individuals.

4. DISCUSSION

4.1 Effects of visitors on study area

This study has shown that the study area, Capo S. Elia promontory, is a natural area very frequented, on the basis of number of visitors recorded in our observations. That is probably due the proximity of the study area with the city of Cagliari, as well as being an area easily accessible by car, public transport and bike. The results of a similar experiments indicated a number of visitors in the natural area highly variable ranging from some hundreds of visitors until more than 6,000 per day (Kim and Daigle, 2012; Mason *et al.*, 2015).

Even the presence of two types of visitors (cyclists and hikers) in Capo S. Elia is related to the closeness to the city and to the easily accessible to the area. In particular, the fact that most of visitors are hikers confirms the main naturalistic vocation of this site, frequented as a recreational area; whereas as a sport area (by cyclist) only from ten years. For this reason, the number of cyclists monitored has been steady during the different seasons.

In addition, the naturalistic/recreational vocation of the area is highlighted by the greatest presence of visitors on Sunday, commonly the free day of the week.

The seasonal variation, with the increase of visitors from winter to summer, is in according to Kim and Daigle (2012). This seasonal variation is due to both favourable weather conditions (increase of the daylight hours, temperatures, and decreases of rains) and flowering of several plant species (Ballantyne and Pickering, 2013).

4.2 Effect of trampling on vegetation

The effect of trampling was greatest in the centre of path as showed by the results of vegetation cover (Mason *et al*., 2015) and vegetation height. Thus, except directly on the paths, the vegetation were not or marginally affected by trampling (Conradi *et al*., 2015). In fact, the maximum trampling occurs in the paths, and it stops out of them (Marion, 1998).

This occurs also because of the vegetation type presents in the site, the Mediterranean maquis characterized mainly by shrubs. In fact, such type of vegetation, very dense, limits the ability of visitors to hike off-trail (Mason *et al*., 2015).

The trampling effect on vegetation of study area, although more evident within the paths, it is shown by the different results of cover vegetation and vegetation height recorded in two transects.

This differences seem linked to the position of transects. T1, which has lower values of cover and height of vegetation, was carried out in the "first path", at the

entrance of the site. On the contrary, T2 was made in a point of the second path which, being equal visitor's affluence, is not reached by all visitors, which don't complete the established route, but they retrace as opposed the first path.

Regarding effects of trampling on the study species *G. alypum*, in the transects it has been detected the same trend already described to coverage and height vegetation, with height and fruiting values nulls in the centre of the path and higher (and comparable) for plots at two and five meters of distance.

Whereas the presence of *G. alypum* only in T2, is probably due to the effect of the highest level of human trampling in T1.

The results achieved on *G. alypum* species, on the one hand demonstrated that human trampling represents a severe impact to reproductive trait (such as fructification) and plant size (height; Fenu *et al*., 2013), on the other hand, confirm the limited ability of visitors to hike off-trail (Mason *et al*., 2015).

4.3 *Globularia alypum* census

The population of *G. alypum* in Capo S. Elia is numerous. The main threat to the population in the study area is therefore represented by the trampling, but the consequences of it seem limited only to paths. A potential threat, now circumscribed, is given by the spread of alien species, in particular *Acacia saligna* in the areas occupied by the species.

Finally, to complete the census of *G. alypum* population in Capo S. Elia station, subsequent monitoring should be carried out.

5. CONCLUSIONS

The results shown in this thesis allowed us to get an assessment about the threat of trampling on the vegetation of the naturalistic area of Capo S. Elia; specifically on *G. alypum* species. The impact of trampling on vegetation and on *G. alypum* in particular, is present but limited to paths, outside which the maquis is too dense to allow hikers to walk on the surroundings. *G. alypum* grows in the zone of the study area less crowed, so where the trampling grade is less.

Monitoring done in order to know the size of the *G. alypum* population reveals the presence of a large population.

The decision to focus the studies on *G. alypum* was taken according to the conservationistic interest of this species, which in Sardinia is found exclusively in Capo S. Elia. Therefore it needs a guardianship plan, for both multiplication and for germplasm conservation (Bocchieri *et al*., 2000).

Capo S. Elia it confirms to be an area with a great naturalistic value, rich in plant species included endemism, with a good conservation state despite the high influx of visitors, but limited to the weekend, especially Sunday.

Based on the results, we can suggest the control and eradication of alien species *Acacia saligna* as a strategy of management, because during the last years, its population has spread in the study area, and in long term could form a threat for *G. alypum* species. Furthermore, in order to avoid the trampling on the areas surrounding the established paths and for raise awareness through the population about naturalness and conservation of this area, guided naturalistic visits on weekends could be organized.

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