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Bryophytes from the wet areas of the Maritime Alps and their use as indicators of anthropic impact

Abstract

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The research was conducted in six areas of the Maritime Alps Natural Park to examine the bryophyte flora of this territory and to identify priority areas for conservation, with particular reference to those where livestock graze and that are marked by evident disturbance. The data on the ecological factors of humidity, light, nitrogen/fertility, and pH were elaborated to address ecological state of the studied sites. Detrended Correspondence Analysis (DCA) was used in order to highlight the role of these factors on the impact of anthropic activity and of grazing. Analysis of the sensitivity of the species to anthropic impact reveals that, on one side, there is a prevalence of species preferring moderate anthropic impact, but on the other hand, many are the species adapted to living in conditions strong anthropic impact.

Key words: Bryophyta, DCA, Conservation, Peat-bogs, Italy.

Introduction

In the course of recent years, several studies have been carried out in the frame of the Cross-border Project between the Maritime Alps Natural Park (Italy) and the Mercantour National Park (France). The objective of these studies was to gain knowledge on the natural patrimony and the biodiversity of the Maritime Alps territory (SIC IT1160056 Alpi Marittime). To this end, between the summer of 2013 and autumn of 2015, a series of explorations was conducted in some areas of the Maritime Alps Natural Park, in particular those characterized by lakes, wet environments and peat-bogs. Based on a large species list, it was possible to develop a series of elaborations and statistical, chorological and ecological considerations; in addition, the bryophytes of these environments can be used as bioindicators of impacts caused by anthropic activities such as grazing of domestic livestock and tourists flow (Diekmann 2003; Kollmann & Fischer 2003; Wamelink & van Dobben 2003; Holt & Miller 2011).

The ecological factors analyzed have a crucial influence on the biological forms of growth of the colonizing species (ephemeral or pioneer) and stress tolerant perennials, that indicate the influence that altitude and the impact of grazing by wild and domestic animals can have on the forms of growth and thus on the selection of species that develop in the six areas studied.

Study Area

The Site of Community Interest (IT1160056 Alpi Marittime) covers a vast portion of the Alpi Marittime Park. It ranges between 700 m a.s.l,. at the valley bottom, to 3297 m a.s.l. at the South Peak of Argentera, the highest peak in the Maritime Alps. The rocky substrata influence the scenery noticeably. Most of the territory outstands by the presence of crystalline rocks that create a harsh, rugged, high-mountain environment, with deep, steep-sided valleys, vast areas with little vegetation and deep avalanche gullies. Elsewhere sedimentary rocks predominate on limestone cliffs and vast scree slopes, open grassland and karst features dominate the scenery. Lower down on the south-facing slopes, we find areas of "sub-Mediterranean" vegetation. The perennial snowfields and remaining relict glaciers are of particular interest. The alpine lakes and the high-altitude hygrophilous marshland environments around them are also of glacial origin. Among the numerous wet environments in the Park, the explorations have focused on some areas in which problems linked to grazing and anthropic impact are more evident. A study of the bryophyte flora was conducted (Fig. 1) in the following six areas:
1. Piano del Valasco (1764 m a.s.l.; Exp. NE; 44°11'55" N – 7°13'58" E)
2. Piano della Casa (1850 m a.s.l.; Exp. N; 44°09'3" N – 7°16'34" E)
3. Lagarot di Laroussa (1971 m a.s.l.; Exp. N; 44°11'59" N – 7°17'36" E)
4. Lago del Vei del Bouc (2049 m a.s.l.; Exp. NE; 44°08'28" N – 7°25'37" E)
5. Lago della Vacca (2266 m a.s.l.; Exp. NW; 44°07'52" N – 7°27'57" E)
6. Lago Villazzo (1838 m a.s.l.; Exp. N; 44°10'04" N – 7°29'52" E)

Materials and methods

In order to characterize the sampling areas, ecological variables were estimated for each species. Humidity (F), light (L), reaction (R) and nitrogen/fertility (N), were successively attributed and elaborated, according to Hill & al. (2007).

The values attributed to each species are based on Ellenberg & al. (1991) adapted by Düll (1991) for the bryophytes, and are elaborated with the INDEXT program (Hill & al. 2000), starting with the ecological values of vascular plants, grouped in quadrants, calculating the average values of each quadrant and using the regressions in order to elaborate new values for the bryophytes. The observations on the ecology of each species were derived from Dierβen (2001).

The data on the ecological parameters were elaborated according to the species reported in the six areas and according to the environmental characteristics of the territories studied using Detrended Correspondence Analysis, in which the scatters of the relevés were separate from those of the species, concentrating in particular on the parameters of humidity, light, nitrogen/fertility, and reaction, in order to highlight the role that these factors have on the impact of anthropic activity and of grazing.

Nomenclature follows Ros & al. (2007) for liverworts and Ros & al. (2013) for mosses. The species distribution refers to Aleffi & al. (2008). The samples are kept at the

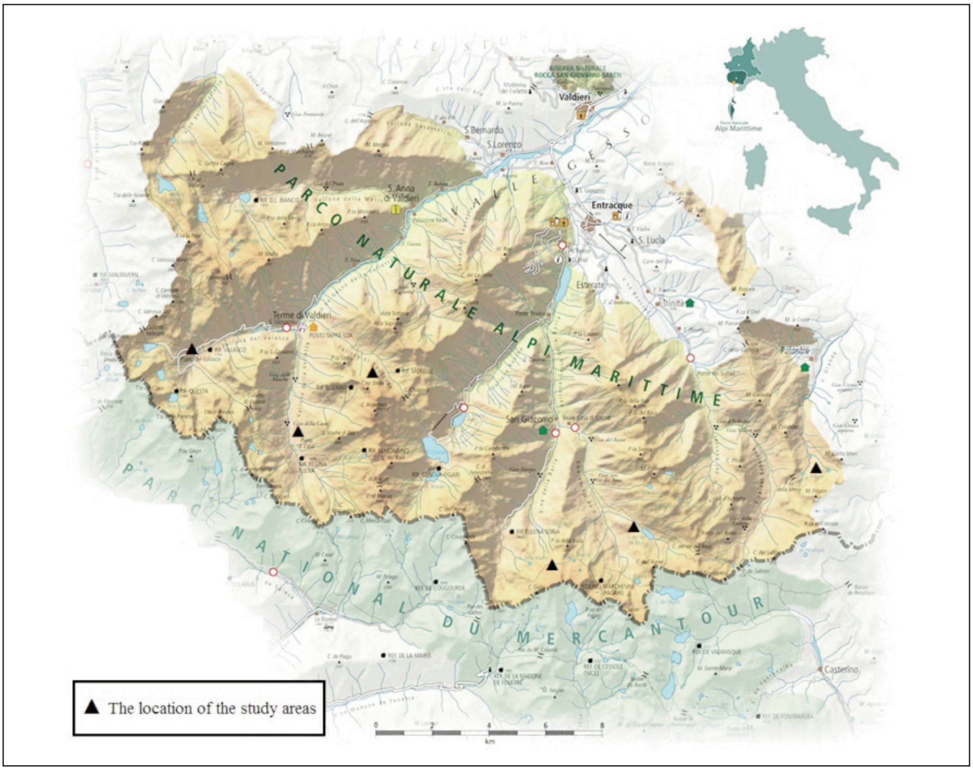

Fig. 1. The map of the Maritime Alps Natural Park with the location of the six study areas.

Herbarium of the Maritime Alps Natural Park and at the Herbarium of the University of Camerino (CAME).

Results and discussion

A total of 199 bryophyte taxa were identified (31 liverworts and 168 mosses). Of these, 8 taxa (1 liverwort and 7 mosses) were new for the Piedmont Region: *Blepharostoma trichophyllum* subsp. *brevirete*, *Brachythecium tommasinii*, *Bryum intermedium*, *Bryum moravicum*, *Bryum sauteri*, *Cratoneuron curvicaule*, *Schistidium crassipilum*, and *Schistidium platyphyllum*. Also, 12 taxa (3 liverworts and 9 mosses) were reported before 1950: this is a group of species whose first and only report was in the late 1800s to early 1900s, and were found on the occasion of that research. Finally, 43 species (8 liverworts and 35 mosses) can be considered rare and chorologically interesting.

Table 1 summarizes the results of the explorations conducted in the six research sites. In particular are listed the species that develop in wet environments and in peat bogs and which have been used for the study. Next to each species (preceded by the abbreviation used in the phase of elaboration of the ecological data), values for the ecological parameters are attributed.

Table 1. List of *taxa* found in the wet environments of the six study areas, indicating for each of them the ecological parameters of humidity (F), light (L), reaction (R) and nitrogen/fertility (N).

Code	*Taxa*	F	L	R	N
Aneu_ping	*Aneura pinguis* (L.) Dumort.	9	8	6	2
Anoe_aest	*Anoectangium aestivum* (Hedw.) Mitt.	7	6	7	2
Atri_undu	*Atrichum undulatum* (Hedw.) P. Beauv.	6	4	5	5
Aula_andr	*Aulacomnium androgynum* (Hedw.) Schwägr.	6	5	3	4
Aula_palu	*Aulacomnium palustre* (Hedw.) Schwägr.	8	7	3	2
Barb_hatc	*Barbilophozia hatcheri* (A. Evans) Loeske	5	6	3	2
Barb_lyco	*Barbilophozia lycopodioides* (Wallr.) Loeske	6	6	4	2
Barbu_bi	*Barbula bicolor* (Bruch & Schimp.) Lindb.	6	5	9	4
Bart_ithy	*Bartramia ithyphylla* Brid.	6	4	4	2
Bart_pomi	*Bartramia pomiformis* Hedw.	6	4	4	2
Blep_tric	*Blepharostoma trichophyllum* subsp. *brevirete* (Bryhn & Kaal.) R.M.Schust.	8	4	5	2
Blin_acut	*Blindia acuta* (Hedw.) Bruch & Schimp.	9	7	5	1
Brac_rivu	*Brachythecium rivulare* Bruch & Schimp.	8	6	6	5
Brac_ruta	*Brachythecium rutabulum* (Hedw.) Bruch & Schimp.	6	6	6	6
Brac_sale	*Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp.	6	5	6	5
Brac_tomm	*Brachythecium tommasinii* (Sendtn. ex Boulay) Ignatov & Huttunen	5	4	8	5
Bryo_ferr	*Bryoerytrophyllum ferruginascens* (Stirt.) Giacom.	6	7	7	2
Bryu_blin	*Bryum blindii* Bruch & Schimp.	6	9	5	4
Bryu_dich	*Bryum dichotomum* Hedw.	5	7	7	7
Bryu_eleg	*Bryum elegans* Nees	3	7	8	3
Bryu_inte	*Bryum intermedium* (Brid.) Blandow	6	8	7	4
Bryu_mora	*Bryum moravicum* Podp.	5	5	6	5
Bryu_mueh	*Bryum muehlenbeckii* Bruch & Schimp.	8	7	5	2
Bryu_saut	*Bryum sauteri* Bruch & Schimp.	5	6	5	5
Bryu_schl	*Bryum schleicheri* DC.	9	7	6	4
Bryu_torq	*Bryum torquescens* Bruch & Schimp.	3	8	7	3
Bryu_weig	*Bryum weigelii* Spreng.	9	7	5	3
Call_cord	*Calliergon cordifolium* (Hedw.) Kindb.	10	5	4	5
Call_cusp	*Calliergonella cuspidata* (Hedw.) Loeske	7	7	7	3
Call_rich	*Calliergon richardsonii* (Mitt.) Kindb.	8	6	4	4
Caly_fiss	*Calypogeia fissa* (L.) Raddi	7	3	3	3
Camp_chry	*Campyliadelphus chrysophyllus* (Brid.) R.S. Chopra	2	8	8	2
Camp_stell	*Campylium stellatum* (Hedw.) Lange & C.E.O.Jensen	8	8	6	2
Ceph_grim	*Cephaloziella grimsulana* (J.B. Jack ex Gottsche & Rabenh.) Lacout.	5	6	5	2
Ceph_leuc	*Cephalozia leucantha* Spruce	7	3	1	1
Cera_purp	*Ceratodon purpureus* (Hedw.) Brid.	4	7	5	3
Chil_poly	*Chiloscyphus polyanthos* (L.) Corda	9	6	5	4
Cinc_font	*Cinclidotus fontinaloides* (Hedw.) P. Beauv.	8	7	7	4
Clim_dend	*Climacium dendroides* (Hedw.) F.Weber & D.Mohr	7	7	5	3
Crat_curv	*Cratoneuron curvicaule* (Jur.) G. Roth	7	6	7	3
Crat_fili	*Cratoneuron filicinum* (Hedw.) Spruce	8	6	7	5
Cten_moll	*Ctenidium molluscum* (Hedw.) Mitt.	6	7	7	2
Cyno_grac	*Cynodontium gracilescens* (F. Weber & D. Mohr) Schimp.	6	4	2	2
Dich_palu	*Dichodontium palustre* (Dicks.) M. Stech	9	7	4	2
Dich_pell	*Dichodontium pellucidum* (Hedw.) Schimp.	8	6	6	2
Dicr_cris	*Dicranoweisia crispula* (Hedw.) Milde	4	7	3	1
Dicr_denu	*Dicranodontium denudatum* (Brid.) E. Britton	6	4	3	2
Dicr_maju	*Dicranum majus* Sm.	6	4	3	2
Dicr_scop	*Dicranum scoparium* Hedw.	5	6	3	2
Dicr_spad	*Dicranum spadiceum* J.E. Zetterst.	6	8	5	2
Dicr_subu	*Dicranella subulata* (Hedw.) Schimp.	5	7	3	2
Dicr_taur	*Dicranum tauricum* Sapjegin	4	4	3	3
Dicr_var	*Dicranella varia* (Hedw.) Schimp.	5	7	7	4
Didy_fall	*Didymodon fallax* (Hedw.) R.H. Zander	4	7	7	3
Didy_insu	*Didymodon insulanus* (De Not.) M.O. Hill	5	6	6	4
Didy_sinu	*Didymodon sinuosus* (Mitt.) Delogne	6	4	7	5
Dist_capi	*Distichium capillaceum* (Hedw.) Bruch & Schimp.	6	6	7	2
Drep_adun	*Drepanocladus aduncus* (Hedw.) Warnst.	10	7	7	6
Enca_cili	*Encalypta ciliata* Hedw.	5	4	7	3

Table 1. continued.

Fiss_adia	*Fissidens adianthoides* Hedw.	7	7	6	2
Fiss_bryo	*Fissidens bryoides* Hedw.	5	4	5	5
Fiss_osmu	*Fissidens osmundoides* Hedw.	7	7	5	2
Fiss_rivu	*Fissidens rivularis* (Spruce) Bruch & al.	9	2	5	4
Font_anti	*Fontinalis antipyretica* (Hedw.) subsp. *antipyretica*	12	6	6	5
Font_grac	*Fontinalis antipyretica* subsp. *gracilis* (Lindb.) Schimp.	12	7	6	4
Grim_alpe	*Grimmia alpestris* (F. Weber & D. Mohr) Schleich.	1	8	5	1
Grim_anom	*Grimmia anomala* Schimp.	6	5	2	2
Grim_caes	*Grimmia caespiticia* (Brid.) Jur.	6	7	1	2
Grim_funa	*Grimmia funalis* (Schwägr.) Bruch & Schimp.	3	7	5	2
Grim_hart	*Grimmia hartmanii* Schimp.	5	3	3	2
Grim_incu	*Grimmia incurva* Schwägr.	1	8	2	2
Grim_mont	*Grimmia montana* Bruch & Schimp.	1	8	4	1
Grim_ramo	*Grimmia ramondii* (Lam. & DC.) Margad.	5	6	3	2
Grim_tric	*Grimmia trichophylla* Grev.	1	7	2	2
Gymn_aeru	*Gymnostomum aeruginosum* Sm.	8	5	6	2
Hedw_cili	*Hedwigia ciliata* (Hedw.) P. Beauv.	1	8	3	1
Hedw_leuc	*Hedwigia ciliata* var. *leucophaea* Bruch & Schimp.	1	8	3	1
Hete_dimo	*Heterocladium dimorphum* (Brid.) Schimp.	5	6	6	2
Hygr_coch	*Hygrohypnum cochlearifolium* (Venturi) Broth.	8	9	4	4
Hygr_duri	*Hygrohypnum duriusculum* (De Not.) D. W. Jamieson	10	5	5	4
Hygr_luri	*Hygrohypnum luridum* (Hedw.) Jenn.	9	6	7	4
Hygr_smit	*Hygrohypnum smithii* (Sw.) Broth.	10	6	6	3
Hylo_pyre	*Hylocomiastrum pyrenaicum* (Spruce) M. Fleisch.	5	6	4	2
Hylo_sple	*Hylocomium splendens* (Hedw.) Bruch et al.	5	6	4	2
Hyme_recu	*Hymenostylium recurvirostrum* (Hedw.) Dixon	8	6	7	2
Hypn_cupr	*Hypnum cupressiforme* var. *subjulaceum* Molendo	4	6	4	4
Isot_alop	*Isothecium alopecuroides* (Dubois) Isov.	6	4	6	5
Isot_myos	*Isothecium myosuroides* Brid.	6	4	4	3
Jung_atro	*Jungermannia atrovirens* Dumort.	8	5	6	3
Jung_hyal	*Jungermannia hyalina* Lyell	8	5	5	3
Jung_obov	*Jungermannia obovata* Nees	9	5	5	3
Jung_pum	*Jungermannia pumila* With.	8	4	5	2
Lesc_saxi	*Lescuraea saxicola* (Schimp.) Molendo	5	6	7	2
Lesk_poly	*Leskea polycarpa* Hedw.	5	6	7	6
Loph_bide	*Lophocolea bidentata* (L.) Dumort.	6	5	4	3
Loph_hete	*Lophocolea heterophylla* (Schrad.) Dumort.	5	4	4	5
Loph_vent	*Lophozia ventricosa* (Dicks.) Dumort.	6	5	2	2
Marc_poly	*Marchantia polymorpha* subsp. *montivagans* Bischl. et Boisselier	8	7	6	4
Mees_triq	*Meesia triquetra* (L. ex Jolich.) Ångstr.	9	7	6	2
Metz_furc	*Metzgeria furcata* (L.) Dumort.	4	5	5	3
Mniu_spin	*Mnium spinosum* (Voit) Schwägr.	6	4	7	3
Mniu_thom	*Mnium thomsonii* Schimp.	6	4	7	3
Nard_geos	*Nardia geoscyphus* (De Not.) Lindb.	7	6	3	2
Orth_cupu	*Orthotrichum cupulatum* Hoffm. ex Brid.	4	7	8	4
Orth_pall	*Orthotrichum pallens* Bruch ex Brid.	4	6	6	4
Oxys_tenu	*Oxystegus tenuirostris* (Hook. & Taylor) A.J.E. Sm.	7	4	3	2
Palu_comm	*Palustriella commutata* (Hedw.) Ochyra	9	6	8	2
Palu_deci	*Palustriella decipiens* (De Not.) Ochyra	9	7	6	2
Palu_falc	*Palustriella falcata* (Brid.) Hedenäs	9	8	6	2
Pell_endi	*Pellia endiviifolia* (Dicks.) Dumort.	8	4	7	4
Pell_epip	*Pellia epiphylla* (L.) Corda	8	4	4	4
Pell_nees	*Pellia neesiana* (Gottsche) Limpr.	8	6	5	3
Phil_arne	*Philonotis arnellii* Husn.	6	6	5	4
Phil_calc	*Philonotis calcarea* (Bruch & Schimp.) Schimp.	9	8	8	2
Phil_font	*Philonotis fontana* (Hedw.) Brid.	9	7	4	3
Phil_marc	*Philonotis marchica* (Hedw.) Brid.	7	6	6	5
Phil_seri	*Philonotis seriata* Mitt.	9	7	4	2
Phil_tome	*Philonotis tomentella* Molendo	9	7	6	2
Plag_cavi	*Plagiothecium cavifolium* (Brid.) Z. Iwats	6	5	6	2

Table 1. continued.

Plag_dent	*Plagiothecium denticulatum* (Hedw.) Schimp. var. *denticulatum*	6	4	4	5
Plag_elli	*Plagiomnium ellipticum* (Brid.) T.J. Kop.	8	7	5	3
Plag_oede	*Plagiopus oederianus* (Sw.) Crum & Anderson var. *oederianus*	5	6	7	2
Plag_pore	*Plagiochila porelloides* (Torrey ex Nees) Lindenb.	6	4	6	4
Plag_succ	*Plagiothecium succulentum* (Wilson) Lindb.	6	3	5	5
Plat_ripa	*Platyhypnidium riparioides* (Hedw.) Dixon	10	4	6	6
Pogo_urni	*Pogonatum urnigerum* P. Beauv.	5	7	3	1
Pohl_crud	*Pohlia cruda* (Hedw.) Lindb.	6	5	5	2
Pohl_drum	*Pohlia drummondii* (Müll. Hal.) A.L.Andrews	6	7	3	2
Pohl_nuta	*Pohlia nutans* (Hedw.) Lindb.	5	5	2	2
Pohl_wahl	*Pohlia wahlenbergii* (F. Weber & D. Mohr) A.I. Andrews var. *wahlenbergii*	8	6	6	4
Poly_alpi	*Polytrichastrum alpinum* (Hedw.) G.L. Sm.	5	6	2	2
Poly_comm	*Polytrichum commune* Hedw.	7	6	2	2
Poly_juni	*Polytrichum juniperinum* Hedw.	5	8	3	2
Poly_pili	*Polytrichum piliferum* Hedw.	3	9	3	1
Pore_plat	*Porella platyphylla* (L.) Pfeiff.	4	6	8	3
Pseu_incu	*Pseudoleskea incurvata* (Hedw.) Loeske	5	6	7	2
Pseu_nerv	*Pseudoleskeella nervosa* (Brid.) Nyholm	5	7	7	2
Pseu_pate	*Pseudoleskea patens* (Lindb.) Kindb.	5	6	7	3
Pseu_tect	*Pseudoleskeella tectorum* (Funck ex Brid.) Kindb. ex Broth.	2	8	7	4
Pter_fili	*Pterigynandrum filiforme* Hedw.	5	6	6	2
Pter_grac	*Pterogonium gracile* (Hedw.) Sm.	4	7	5	2
Ptyc_bimu	*Ptychostomum pseudotriquetrum* var. *bimum* (Schreb.) Dm.T.Holyoak & N.Pedersen	9	8	6	3
Ptyc_comp	*Ptychostomum compactum* Hornsch.	6	9	7	4
Ptyc_imbr	*Ptychostomum imbricatulum* (Müll. Hal.) Holyoak & Pedersen	4	7	6	5
Ptyc_pall	*Ptychostomum pallens* (Sw.) J.R. Spence	7	7	6	4
Ptyc_palsc	*Ptychostomum pallescens* (Schleich. ex Schwägr.) J.R. Spence	5	7	6	4
Ptyc_plic	*Ptychodium plicatum* (Schleich. ex F.Weber & D.Mohr) Schimp.	5	6	7	2
Ptyc_pseu	*Ptychostomum pseudotriquetrum* (Hedw.) J.R.Spence & H.P.Ramsay var. *pseudotriquetrum*	9	8	6	3
Raco_cane	*Racomitrium canescens* (Hedw.) Brid.	3	8	6	2
Raco_elon	*Racomitrium elongatum* Ehrh. ex Friswoll	4	8	4	2
Raco_eric	*Racomitrium ericoides* (Weber ex Brid.) Brid.	5	7	4	2
Raco_micr	*Racomitrium microcarpon* (Hedw.) Brid.	5	7	6	1
Raco_sude	*Racomitrium sudeticum* (Funck) Bruch & Schimp.	3	7	2	1
Raco-obtu	*Racomitrium obtusum* (Brid.) Brid.	2	7	2	1
Radu_lind	*Radula lindenbergiana* Gottsche ex C. Hartm.	5	6	6	3
Rhiz_magn	*Rhizomnium magnifolium* (Horik.) T.J.Kop.	9	6	5	3
Rhiz_punc	*Rhizomnium punctatum* (Hedw.) T.J.Kop.	8	5	5	4
Rhyt_squar	*Rhytidiadelphus squarrosus* (Hedw.) Warnst.	5	7	5	4
Rhyt_triq	*Rhytidiadelphus triquetrus* (Hedw.) Warnst.	6	6	6	3
Sani_unci	*Sanionia uncinata* (Hedw.) Loeske	6	6	4	2
Scap_aequ	*Scapania aequiloba* (Schwaegr.) Dumort.	7	5	7	2
Scap_curt	*Scapania curta* (Mart.) Dumort.	6	6	3	2
Scap_helv	*Scapania helvetica* Gottsche	6	7	6	2
Scap_irri	*Scapania irrigua* (Nees) Nees	8	7	4	2
Scap_nemo	*Scapania nemorea* (L.) Grolle	7	5	4	2
Scap_suba	*Scapania subalpina* (Nees ex Lindenb.) Dumort.	8	7	4	2
Scap_uligi	*Scapania uliginosa* (Sw. ex Lindenb.) Dumort.	9	7	4	2
Scap_undu	*Scapania undulata* (L.) Dumort.	10	6	4	2
Schi_apoc	*Schistidium apocarpum* (Hedw.) Bruch & Schimp.	2	7	7	4
Schi_cras	*Schistidium crassipilum* Blom	1	7	8	4
Schi_platy	*Schistidium platyphyllum* (Mitt.) H.Perss. subsp. *platyphyllum*	8	7	5	3
Schi_rivu	*Schistidium rivulare* (Brid.) Podp. subsp. *rivulare*	8	7	5	3
Sc-hy_plum	*Sciuro-hypnum plumosum* (Hedw.) Ignatov & Huttunen	8	5	4	3
Sc-hy_star	*Sciuro-hypnum starkei* (Brid.) Ignatov & Huttunen	7	6	5	2
Scor_coss	*Scorpidium cossonii* (Schimp.) Hedenäs	8	8	7	2
Scor_scor	*Scorpidium scorpioides* (Hedw.) Limpr.	10	8	6	2
Spha_capi	*Sphagnum capillifolium* (Ehrh.) Hedw.	7	7	2	2
Spha_cent	*Sphagnum centrale* C.E.O. Jensen ex Arn. & C.E.O. Jensen	8	7	3	2
Spha_cont	*Sphagnum contortum* Schultz	9	8	5	2

Table 1. continued.

Spha_fall	*Sphagnum fallax* (H.Klinggr.) H.Klinggr.	9	7	2	3
Spha_mage	*Sphagnum magellanicum* Brid.	8	8	1	1
Spha_palu	*Sphagnum palustre* L.	8	7	3	2
Spha_plat	*Sphagnum platyphyllum* (Lindb. ex Braithw.) Warnst.	9	8	5	2
Spha_russ	*Sphagnum russowii* Warnst.	7	6	2	2
Spha_squa	*Sphagnum squarrosum* Crome	9	6	4	3
Spha_subs	*Sphagnum subsecundum* Nees ex Sturm	9	8	4	2
Spha_tene	*Sphagnum capillifolium* var. *tenerum* (Sull. & Lesq. ex Sull.) H. A. Crum	7	7	2	2
Spha_tenel	*Sphagnum tenellum* (Brid.) Bory	8	8	1	1
Spha_tere	*Sphagnum teres* (Schimp.) Ångstr.	9	7	4	2
Stra_stram	*Straminergon stramineum* (Dicks. ex Brid.) Hedenäs	9	7	3	2
Synt_calc	*Syntrichia calcicola* J.J. Amann	3	8	7	4
Synt_norv	*Syntrichia norvegica* F. Weber	4	8	7	2
Synt_rura	*Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr var. *ruralis*	3	8	7	4
Tetr_pell	*Tetraphis pellucida* Hedw.	6	3	3	3
Tort_hopp	*Tortula hoppeana* (Hedw.) Limpr.	2	9	7	2
Tort_mura	*Tortula muralis* Hedw.	2	6	8	5
Tort_tort	*Tortella tortuosa* (Hedw.) Limpr. var. *tortuosa*	4	7	7	2
Warn_exan	*Warnstorfia exannulata* (Schimp.) Loeske	9	8	4	2
Warn_sarm	*Warnstorfia sarmentosa* (Wahlenb.) Hedenäs	9	8	5	2

Humidity

The hygrophytes (30.89%) and the mesophytes (36.62%) represent the dominant group. Conversely, the xerophytes (11.52%) represent a smaller group that grow prevalently on the rocky substratum directly exposed to sunlight.

The first axis of the DCA graph (Fig. 2) distinguishes various degrees of humidity of the individual relevés. There is a distinction between the various points of relevés of the Lago del Vej del Bouc (white circles) and Valasco (white squares), and the points that are dryer (GPS 68, grey squares of the dry, rocky grazing lands near the Lago della Vacca and GPS 54, dry grazing lands of the Lago del Vej del Bouc).

Some relevés of the Lago Villazzo (grey rhombuses), of the Piano del Valasco and the Lago del Vej del Bouc, which are grazed humid areas or near-grazing areas, tend to be in intermediate positions on the graph. This is probably due to the presence of species more adapted to situations of dehydration, and whose growth can be favored by these conditions of disturbance. These species (e.g. *Brachythecium tommasinii*, *Climacium dendroides*, *Phylonotis tomentella*, *Pseudoleskea patens*) are well remarked by the grey square in the DCA species ordination (Fig. 3).

Light

The bryophytes that predominate in the environments studied are species adapted to living in environments that are moderately to strongly illuminated, conditions linked to the strong exposition to sunlight of these habitats, above all during the summer. Also in this case, these are species typical of peat-bogs that adapt to conditions of extreme climatic and environmental variability.

The DCA for the parameter of light (Fig. 4) does not seem to show any particular differences. Rather, it seems to reflect the divisions of the parameter of humidity. However, it should be noted that about half of the species identified are very adaptable

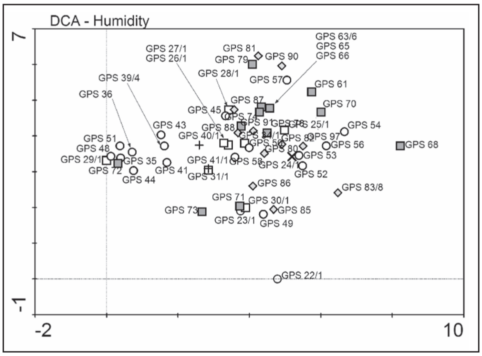

Fig. 2. The DCA humidity graph of the relevés.

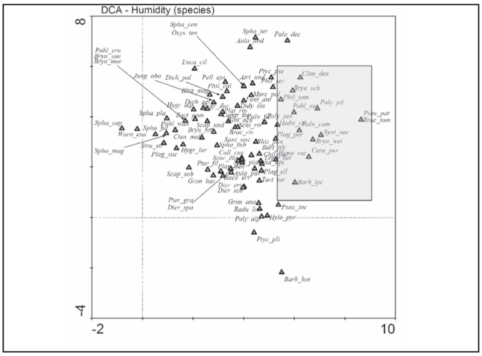

Fig. 3. The DCA humidity ordination of the species.

regarding this ecological parameter, inasmuch as they can live in conditions of shade and those of full sunlight.

However, we can note a certain division along the second axis, above all if it is compared with the axis of the species (Fig. 5) where at the base there are species that are distinguished from the others because they traditionally live in conditions more typical of underbrush.

Nitrogen/fertility

Analyzing the graph for the values of nitrogen/fertility of the substratum (Fig. 6), the most nitrophilous species are located on the right (white rectangle) while the least nitrophilous ones are on the left (grey rectangle).

According to Hill & Preston (1998) and Dierβen (2001), the species that are more eutrophic/nitrophilic are *Tortula hoppeana, Ceratodon purpureus, Leskea polycarpa* and *Brachythecium rutabulum*. All of them are found on the right in Fig. 6.

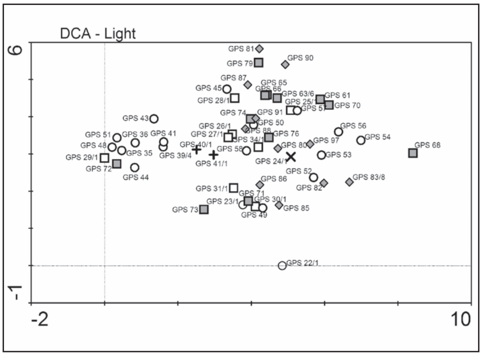

Fig. 4. The DCA for the parameter of light of the relevés.

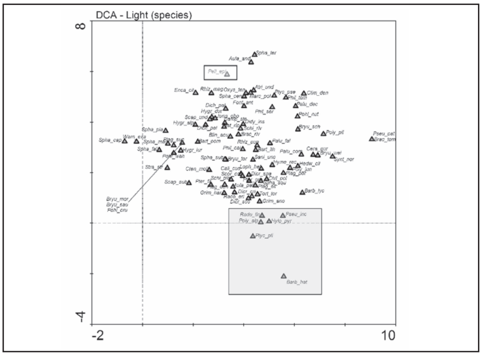

Fig. 5. The DCA light graph of the species.

The species classified by Dierβen (2001) as typical of a substratum with an average content of nutrients (m nitrophyt) are *Aulacomnium androgynum, Bryum dichotomum, Calliergon cordifolium, Calliergonella cuspidata, Lophocolea heterophylla, Marchantia polymorpha subsp. montivagans, Orthotrichum pallens, Ptychostomum imbricatulum, Ptychostomum pallescens, Rhytidiadelphus squarrosus, Rhytidiadelphus triquetrus, Scapania irrigua, Sciuro-hypnum starkei* and *Sphagnum squarrosum*. These species are distributed prevalently in the right part of Fig. 6. Instead, the indicator species of a low nutrients content (oligotrophic) are *Hygrohypnum cochlearifolium, Hygrohypnum smithii, Jungermannia obovata, Scapania undulata,* and *Blindia acuta*. These species, as shown by the grey rectangle, are located in the left part of Fig. 6.

Along the second axis, the species in a higher position seem to be those that grow where there is water, while in a lower position are those that grow in drier sites.

Observing the same graph regarding the relevés (Fig. 7), most of the grazed sites, such as those of the Lago del Vej del Bouc, are located on the right, while those of mires and humid zones, notoriously poorer in nutrients, are on the left. Some of these, even though they are in humid zones such as GPS52, GPS53 together with some of Lago Villazzo (grey rhombuses: GPS82 and 83) and of the Lago della Vacca (grey squares: GPS 70), are found on the right, near those of grazing sites. This is the same as in Valasco (white squares) which, except for one, are found prevalently in the central part.

pH

Regarding acidity, a distribution similar to that of the previous graphs is seen along the first axis also in the two graphs for soil pH (Figs. 8, 9). The presence of species of the *Sphagnum* genus (grey square), as shown by the grey rectangle, which are indicators of the maximum values of acidity, distinguish some survey observations from the others in Fig. 8. It appears clear that the relevés (in wet zones as well) in the area of the Valasco (Fig. 9, white squares) are almost all located in the central part of the graph, indicating intermediate values of acidity. In this area, *Calliergonella cuspidata* was found with greater frequency (3 relevés). This species typical of basic environments can thus be considered an indicator element for an anomalous increase in pH.

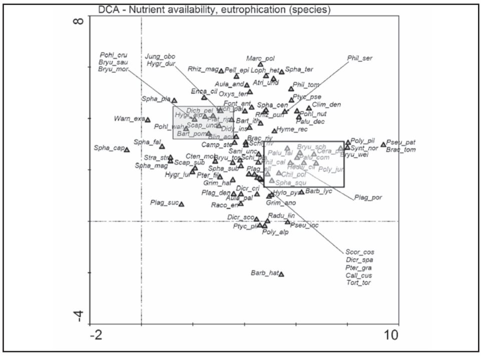

Fig. 6. The DCA graph for the nutrient availability of the species.

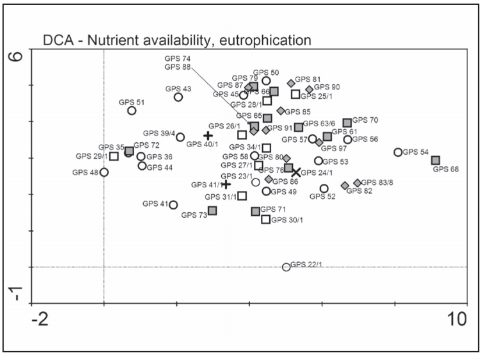

Fig. 7. The DCA graph of the relevés for the values of nitrogen/fertility of the substratum.

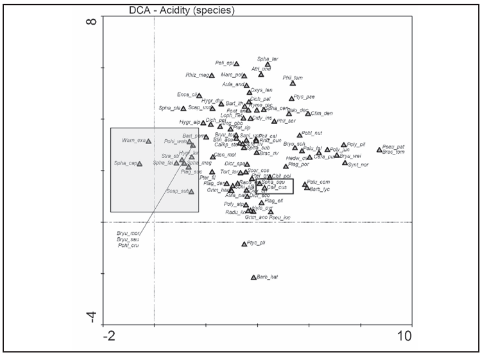

Fig. 8. The DCA graph for soil pH of the species.

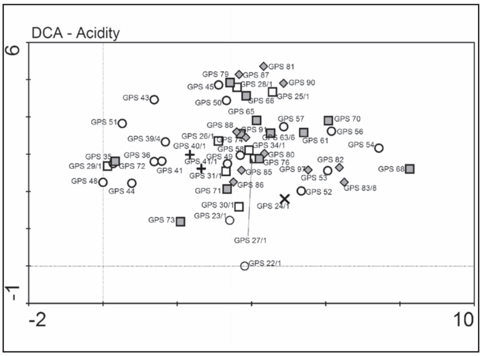

Fig. 9. The DCA graph for soil pH of the relevés.

Sensitivity of the species to anthropic impact

Analysis of the sensitivity of the species to anthropic impact reveals that on the one hand, there is a prevalence of species that prefer moderate anthropic impact, but on the other hand, on the whole, there are many species adapted to living in conditions of moderate or strong anthropic impact, an observation that should be related, especially in some sites, to the high degree of trampling by livestock, which inevitably conditions the species component.

Dierβen (2001) identifies a series of indicator species for the presence of different levels of anthropic impact. On this basis, it was possible to identify target species that are indicators of natural conditions and/or of moderate anthropization and of deterioration of the studied areas, and in this way proceed to characterize the study areas, through analysis of the ecological parameters considered up to this point, and applied to the species identified. In this way, it was possible to obtain criteria and indications for planning actions of direct and indirect guardianship, protection and restoration of the habitats.

We list here, on the basis of the degree of anthropic impact, the species that were noted during the course of this study that better than others are able to represent the various degrees of anthropization and that can be used in the future as indicator species for these phenomena.

Indicator species of high/strong anthropic impact (Eu-polyhem)
- *Bryum dichotomum* Hedw. (Lago del Vej del Bouc, bare soil)

Indicator species of high anthropic impact (Euhem)
- *Bryum sauteri* Bruch & Schimp. (Lagarot di Laroussa, dripping wall; Lago del Vej del Bouc, peat-bog)
- *Dicranella varia* (Hedw.) Schimp. (Lago del Vej del Bouc)

Indicator species of moderate/strong anthropic impact (Meso-polyhem)
- *Ceratodon purpureus* (Hedw.) Brid. (Piano della Casa, bare soil; Lago del Vej del Bouc, bare soil; Lago Villazzo, banks of the river)
- *Didymodon fallax* (Hedw.) R.H. Zander (Lagarot di Laroussa, wet meadow)

- *Pohlia nutans* (Hedw.) Lindb. (Piano della Casa; Lago del Vej del Bouc, bare soil; Gias Prato, wet meadow; Lago Vacca, banks of the river)
- *Tortula muralis* Hedw. (Piano della Casa, on soil)

Indicator species of moderate/high anthropic impact (Meso-Euhem)
- *Brachythecium rutabulum* (Hedw.) Bruch & Schimp. (Lago Villazzo, banks of the river)
- *Chiloscyphus polyanthos* (L.) Corda (Lago del Vej del Bouc, peat-bog)
- *Cinclidotus fontinaloides* (Hedw.) P. Beauv. (Lagarot di Laroussa, wet meadow)
- *Dicranella subulata* (Hedw.) Schimp. (Piano del Valasco, bare soil)
- *Didymodon insulanus* (De Not.) M.O. Hill (Piano del Valasco, banks of the river)
- *Lophocolea heterophylla* (Schrad.) Dumort. (Lago del Vej del Bouc, bare soil)
- *Plagiomnium ellipticum* (Brid.) T.J. Kop. (Lago del Vej del Bouc, peat-bog; Piano della Casa, bare soil)
- *Platyhypnidium riparioides* (Hedw.) Dixon (Piano del Valasco, banks of the river; Lagarot di Laroussa, wet meadow)
- *Ptychostomum imbricatulum* (Müll. Hal.) Holyoak & Pedersen (Piano della Casa, on soil)
- *Ptychostomum pallescens* (Schleich. ex Schwägr.) J.R. Spence (Lagarot di Laroussa, wet meadow)

Conclusions

The explorations conducted in the six areas have allowed us to achieve an in depth study of the bryophyte flora in a territory of the Alps whose bryophytes have received little attention so far. We offer below a summary of the concluding considerations that can serve as the foundations for future research to monitor the areas studied and identify opportune actions to safeguard these environments.

Some areas (Piano del Valasco, Piano della Casa), are more subject to the effects of both grazing and the influx of tourists, which in some periods of the year, reaches unsustainable levels for an environment of such extremely fragile equilibrium as that of a mire. The floating marshy peat mats often appear to have been crushed underfoot by tourists. In these areas, one can observe that alongside the typical flora of peat-bogs represented by *Sphagnum*, there is the development of a more banal and ubiquitous ruderal and anthropic flora; in the part uphill, where the valley closes near the waterfall, the pressure from cattle grazing appears greater, and the bryophyte flora concentrates in proximity of boulders and strips of larch groves on the edges of the Piano.

Lago del Vej del Buc, Lago Villazzo and Lago della Vacca appears to be strongly conditioned by the notable impact of livestock grazing. The pet-bog appears to be particularly damaged by the trampling of animals, while in the places where there is the greatest trampling, the vegetation appears to be characterized by ruderal and ubiquitous species typical of grazing environments. On the lake shore where there has been no trampling or a lesser degree of trampling, there are traces of a *Sphagnum* bog, even though observation of the state of conservation of the *Sphagnum* indicates that it suffers from the aridity and the state of drying of the summer, in all likelihood related to the karstic nature of the subsurface. In fact, in places where the water reappears, species typical of wet environments are seen. It should be noted that the peat-bog is subject to trampling by animals with consequent damage and impoverishment of its species component.

The Lagarot di Laroussa is the only site with the greatest characteristics of naturalness. In fact, no livestock were seen there. The shores of the small lake, which appear to be in an excellent state of conservation, attract afternoon visits of chamois who go there to drink. The influx of tourists seems to be quite orderly and respectful of the environment. In Lagarot, as in the other sites, *Sphagnum* were not observed, but unlike the others, the aquatic and wet environment flora is rich, making this site an environment that is surely interesting and to be used as a model of conservation, also for the other sites.

The indicator species of anthropic impact identified during this research, could be used for future monitoring efforts, at least in areas with elevated anthropic impact. Precisely because of the ecological and natural characteristics described in this work (colonizing species or those linked to a certain chemism of the waters or substrata), they adapt to living well in situations where there is a high degree of anthropization.

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