15. Multivariate analysis of the syntaxa

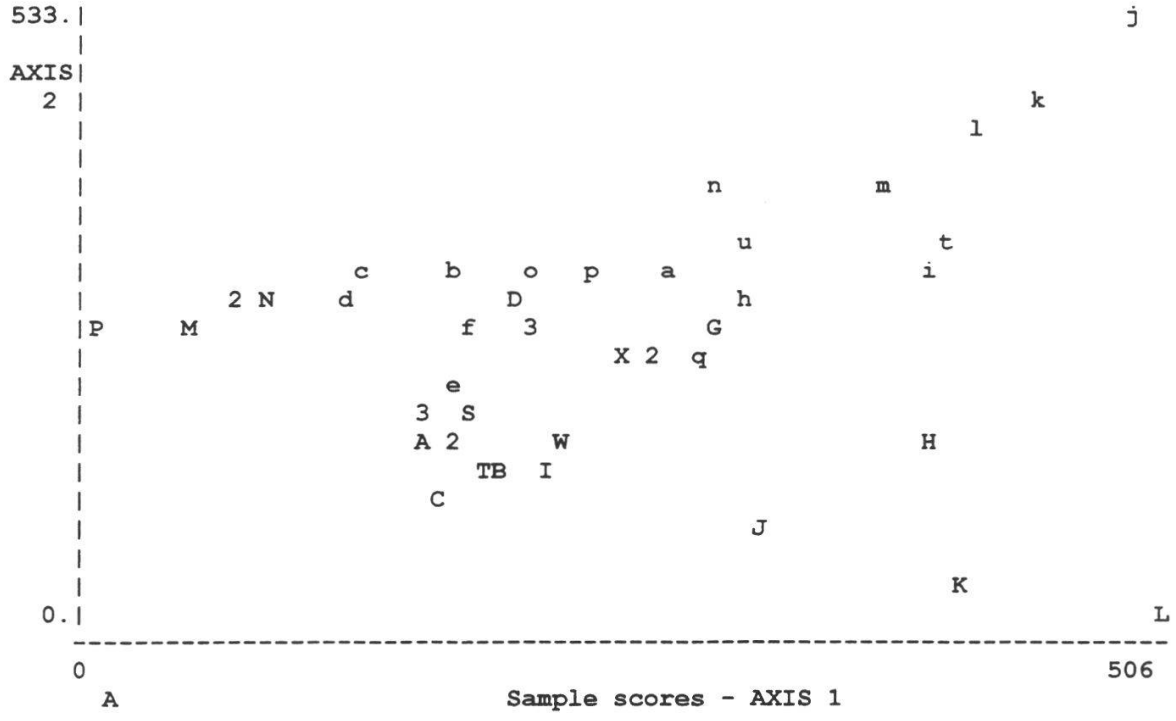
We used detrended correspondence analysis (DCA) and weighted pair group cluster analysis (MVSP Software, KOVACH 1995) to estimate the relationships between the syntaxa of the vegetation. All (47) subassociations or associations (except *Ranunculo oreophili-Polygonetum aviculais*) were included in the analysis. Each syntaxon was represented by a complete list of species with frequency classes (1-5) as the abundance value of each species. Rare species found infrequently (class 1) in one syntaxon only were excluded from the general matrix before the processing. The matrix analyzed included 651 species.

The DCA -ordination patterns are represented in Fig. 15.1. on three main axes. The results of the cluster analysis are represented in the dendrogramm (Fig. 15.2.). Overall, the results showed a considerable correspondence with the position of the syntaxa in the floristic system, but some discrepancies have also been noted.

Communities of *Juncetea trifidi, Carici rupestris-Kobresietea bellardii* and *Polygono viviparum-Salicetum kazbekensis* form a separate group in all projections. They build a distinct cluster as well. All of these low productive alpine communities are typical of windward slopes with thin or absent snow cover in winter, so the extreme environment is responsible for their distinct floristic composition. On the other hand, as we have noted above, the floristic differences between *Juncetea trifidi* and *Carici rupestris-Kobresietea bellardii* are very subtle in our region. Perhaps, it would be better to consider them within the same class. The position of *Polygono viviparum-Salicetum kazbekensis* in *Loiseleurio-Vaccinietea* is more or less formal and might be revised in the future.

It is necessary to point out that the position of *Violo altaicae-Festucetum variae* is quite different from *Juncetea trifidi (Anemonion speciosae)* syntaxa. It confirms the position of the Caucasian *Festuca varia* dominated grasslands within *Nardetalia*.

All syntaxa of *Mulgedio-Aconitetea*, except one, form a separate cluster (Fig.15.2.). Their position on the DCA -axis surface is rather distinct as well. *Senecioni propinqui-Betuletum litwinowii* is positioned closely to the subalpine tall herbaceous communities, as we have discussed above (ch.13).



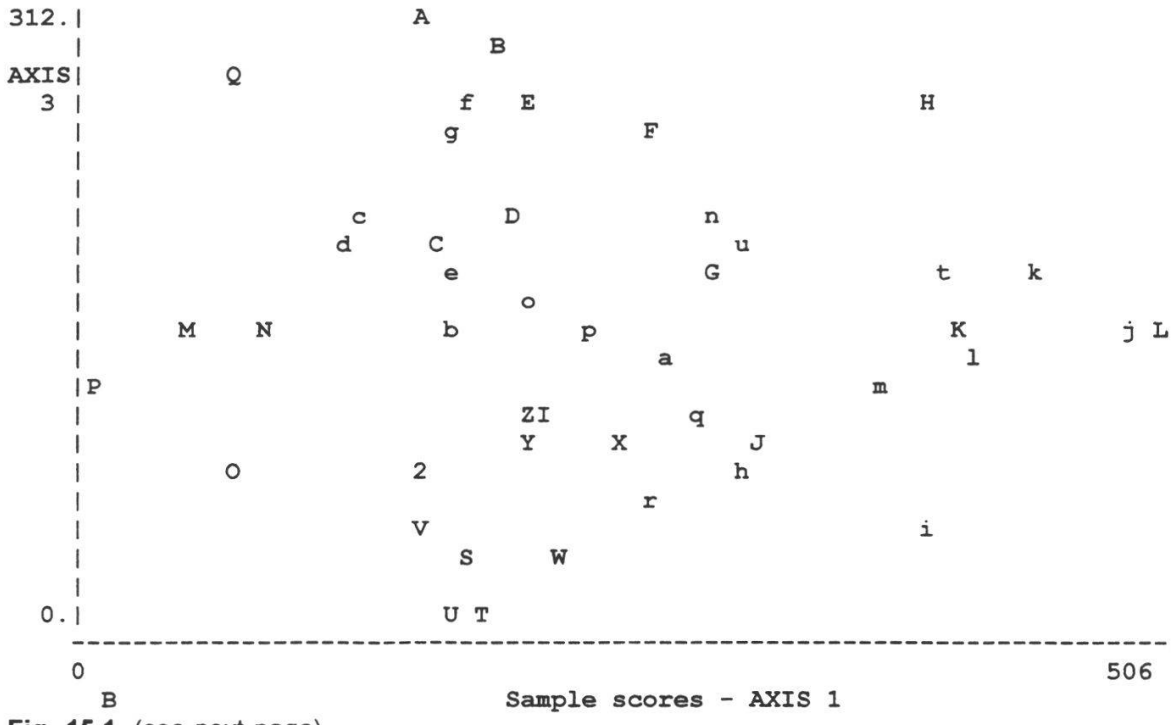


Fig. 15.1. (see next page)

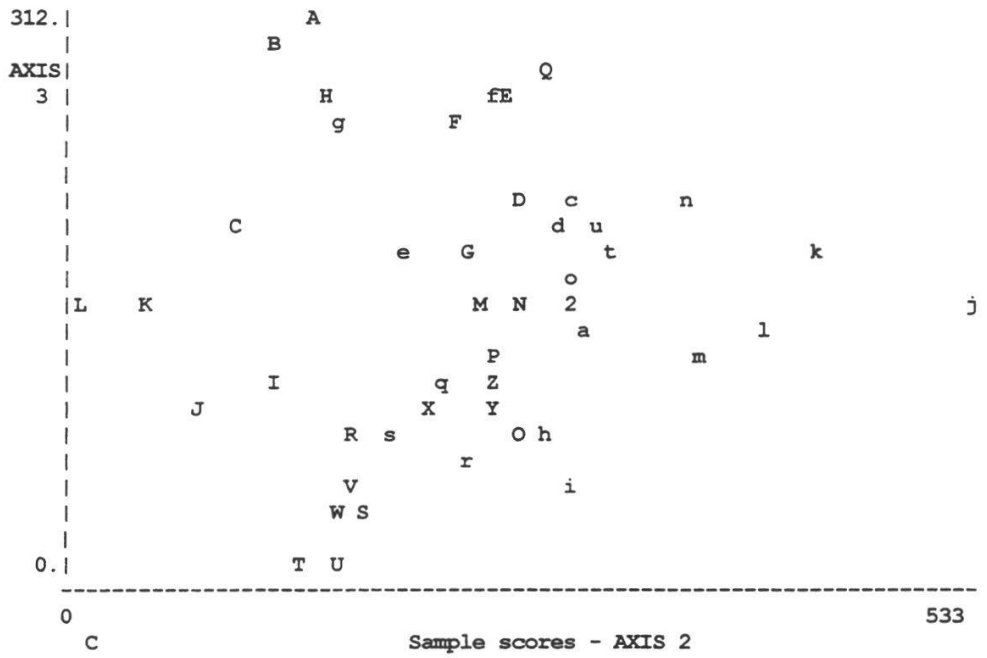


Fig. 15.1.

Results of DCA-analysis (projection of syntaxa on three main ordination axes) Syntaxa:

Thlaspietea rotundifolii:

A - *Veronico minutae-Chaerophylletum humilis typicum*, **B** - *V.t.-Ch.h. lamietosum tomentosi*, **C** - *V.t.-Ch.h. saxifragetosum flagellaris*, **D** - *Hyalopoo ponticae-Oxyrietum digynae ranunculetosum oreophili*, **E** - *H.p.-O.d. typicum*, **F** - *Scrophulario olympicae-Epilobietum dodonaei*, **G** - *Dicranoweisio crispulae-Rubetum idaei*, **H** - *Silene compactae-Salicetum elbursensis*.

Asplenietea trichomanis:

I - *Potentilletum divinae*, **J** - *Astragaletum levieri*, **K** - *Galio valantioides-Polypodietum vulgaris*, **L** - *Thymo-Seselietum petraei*.

Scheuchzerio-Caricetea fuscae:

M - *Caro caucasici-Caricetum nigrae salicetosum kazbekensis*, **N** - *C.c.-C.n. typicum*, **O** - *Swertio ibericae-Caricetum nigrae*, **P** - *Caricetum rostratae*.

Montio-Cardaminetea: **Q** - *Cerastio cerastioidis-Cardaminetum uliginosi*.

Carici rupestris-Kobresietea bellardii:

R - *Drabo scabri-Kobresietum schoenoidis*, **S** - *Alchemillo-Kobresietum capilliformis*.

Juncetea trifidi:

T - *Campanulo ciliatae-Chamaesciadietum acaulis*, **U** - *Pediculari comosae-Eritrichietum caucasici oxytropidetosum kubanensis*, **V** - *P.c.-E.c. typicum*, **W** - *P.c.-E.c. bromopsietosum variegatae*.

Calluno-Ulicetea:

X - *Violo altaicae-Festucetum variae geranietosum renardii*, **Y** - *V.a.-F.v. typicum*, **Z** - *V.a.-F.v. nardetosum*, **a** - *Hedysaro caucasicae-Geranietum gymnocauli senecionetosum kolenatiani*, **b** - *H.c.-G.g. typicum*.

Salicetea herbaceae:

c - *Ranunculetum brachylobi*, **d** - *Hyalopoo ponticae-Pedicularietum nordmannianae*, **e** - *Saxifragetum sibiricae typicum*, **f** - *S.s. primuletosum amoenae*, **g** - *S.s. saxifragetosum moschatae*.

Mulgedio-Aconitetea:

h - *Betonici macranthae-Calamagrostietum arundinaceae typicum*, **i** - *B.m.-C.a. veronicetosum peduncularis*, **j** - *Anthrisco sylvestris-Rumicetum alpini typicum*, **k** - *A.s.-R.a. senecionetosum platyphylloidis*, **l** - *Cephalario giganteae-Ligusticetum alani*, **m** - *Poetum longifoliae*.

Loiseleurio-Vaccinietea:

n - *Lerchenfeldio-Rhododendretum caucasici L.-R.c. oxalidetosum*, **o** - *L.-R.c. typicum*, **p** - *L.-R.c. pleurozietosum*, **q** - *Aconito nasuti-Juniperetum typicum*, **r** - *A.n.-J. chaerophylletosum rosei*, **s** - *Polygono viviparum-Salicetum kazbekensis*.

t - *D.c. Senecioni nemorensis-Betuletum litwinowii*.

Vaccinio-Piceetea: **u** - *Rhododendro caucasici-Betuletum litwinowii*.

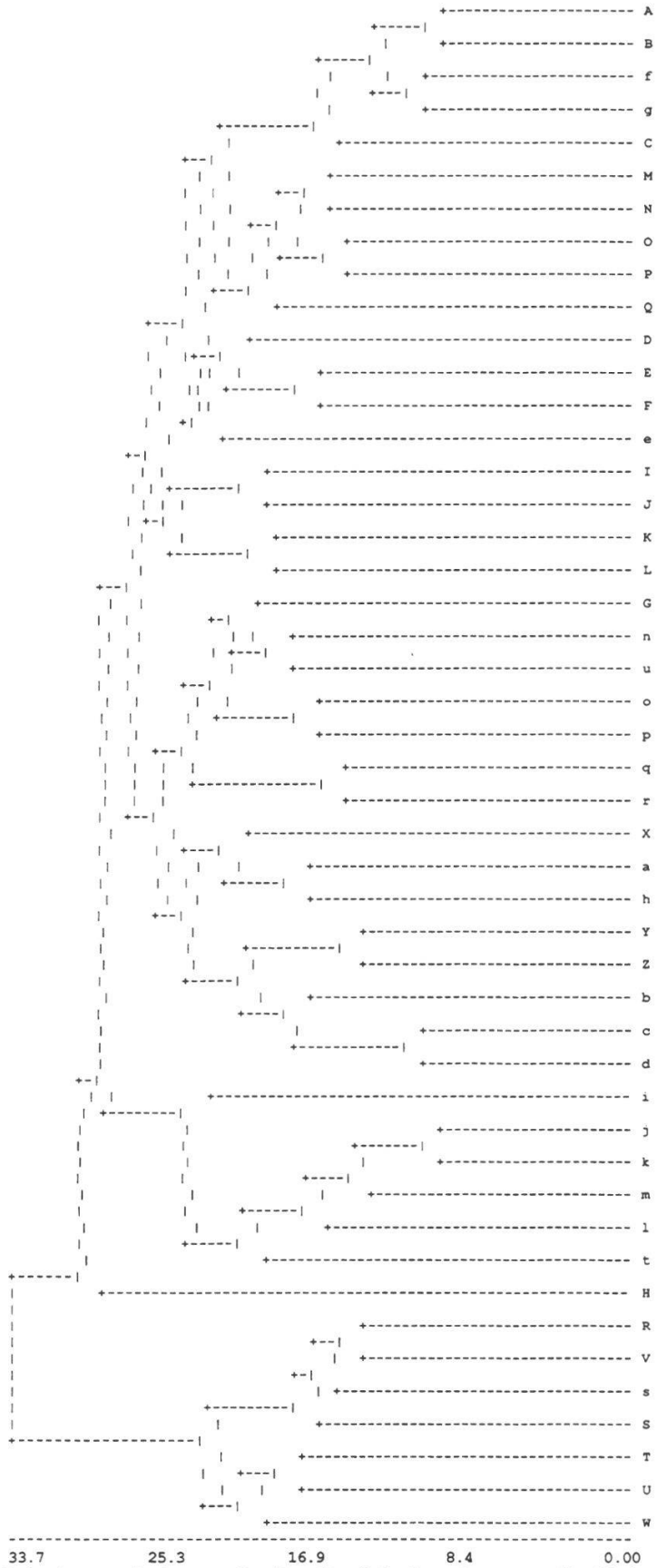


Fig.15.2. Dendrogram of cluster analysis results. For the list of syntaxa see fig.15.1.

The alpine grassland (*Calluno-Ulicetea*) forms another compact group in the dendrogram. It occupies the central part of the ordination surfaces. The position can be attributed to rather favourable ecological conditions for this community where many alpine, as well as some subalpine species can grow. We consider *Hedysaro caucasicae-Geranietum gymnocauli* as the "core" (according to KEDDY 1989, 1990) alpine community.

Rhododendron- and *Juniperus*-shrubs (*Loiseleurio-Vaccinietea*) are positioned close to the *Nardetalia* (Fig. 15.1.). One of the birch woodlands (*Rhododendro caucasici-Betuletum litwinowii*) also fits into this group.

Despite their significant floristic variability, rock outcrop communities (*Asplenietea trichomanis*) form a separate cluster in the dendrogram (Fig. 15.2.). They assume a relatively isolated position in the ordination surfaces as well. Syntaxa of *Thlaspietea rotundifolii* can be divided into 3 groups. *Silene compactae-Salicetum elbursensis* has the most distinct position from all other communities due to its great floristic richness and varied composition. Subalpine stable screes (*Dicranoweisio crispulae-Rubetum idaei*) are very closely related to *Rhododendron* - scrub (*Lerchenfeldio-Rhododendretum caucasici*). On the other hand alpine and subalpine unstable screes are the closest to the snowbeds and fens.

Alpine fens (*Scheuchzerio-Caricetea fuscae*) demonstrated a very distinct position on the first ordination axis (Fig. 15.1.a). The dry rock communities of the lower altitudes (*Thymo-Seselietum petraei*) occupy the opposite position. Therefore, we can consider the first axis as a complex moisture-altitude gradient.

The interpretation of the ecological sense of the second axis is more difficult. Species-poor high productive *Anthrisco sylvestris-Rumicetum alpini* communities occupied the extreme positions on the one side, on the other side there were species of rich unproductive dry rock communities (*Thymo-Seselietum petraei*).

Acknowledgements

I would like to thank all members of Moscow University expeditions, especially A. Egorov, O. Gorbachevskaya, S. Zenyakin, O. Cherednichenko, A. Aksenova, A. Sennov, G. Semenova, N. Lubeznova, for their indispensable help in the fieldwork. Professor B.M. Mirkin was the first who actively stimulate our syntaxonomic studies in Teberda. A.R. Ishbirdin, A.I. Solomeshch and V.V. Akatov made many helpful comments on the tables.
I am particularly thankful to K. Thompson for the English text correction and M.S. Blinnikov for helpful comments. D.E. Aksenov made the computer version of the map of Teberda Reserve. E.A. Ignatova determined all bryophyte samples. I would like to thank R. Stupf and T. Wilhalm for their help with the manuscript. Thanks are also due to the administration and staff of Teberda State Reserve for their continual assistance in the organization of field research.
John D. and Catherine T. MacArthur Foundation supported our investigations, as well as Russian Foundation for Fundamental Research (N 93-04-6498, 99-04-48012). Prof. Peter Edwards and Rübel Foundation made possible this publication in "Veröffentlichungen des Geobotanischen Institutes der ETH" series.