Meadows in the Krkonoše Mountains: What We Know About their Variability and Management

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Abstract

Meadows in the Krkonoše Mountains were established during the mountain colonisation of the 16th and 17th centuries. Grasslands form an almost continuous chain of treeless areas from the foothills to the alpine areas, enabling thus contact of plants of different origin. Unique communities including forest plants, plants ascending from low altitudes, and alpine plants descending from high altitudes have been formed.

The meadows are also important habitats for several rare or even endemic alpine species. Great richness in species is characteristic of these communities. Species composition as well as processes in communities is determined not only by management but also by local environmental conditions (soil and nutrient supply mainly).

The species composition of grasslands is very sensitive to small changes in management. Most meadows have been abandoned since the Second World War, and their present condition is bad. These systems develop quickly into forests or into degradation phases dominated by one or two species. The main problem connected with the degradation phases is that introduction of the original management does not lead to the formation of the original communities. Thus, new management practices should be found.

Introduction

There are several centres of species-rich grasslands in the Czech Republic. Two of these systems have become modelling objects duriong the last years: cut meadows in the Bílé Karpaty and Krkonoše Mountains. There are no montane meadows of comparable size in the Herzynian part of the Czech Republic as in the Krkonoše Mountains; this type of meadows is almost absent at comparable altitudes in the Polish part of the mountains. Now, most of the area studied is covered by the Krkonoše National Park This area belongs to the most endangered ones in the World: damage is caused by severe air pollution, meadow's abandonment, and overuse of the land by sports activities, mainly in winter time.

This paper focusing on mountain meadows is based mainly on the paper by Krahulec et al. (1997) written in Czech language and on some other research partly published in Czech.

Characteristics of the Area

The altitude of the Krkonoše Mountains (the western part of the Sudeten Mountains, 50°46´ - 50°36´ N latitude, 15°27´-15°55´ E longitude) ranges between 400 meters and 1,600 meters. Geologicall, the mountains are formed by intrusive and metamorphic rocks: granite, gneiss, mica-schist; only at the periphery of the mountains are there other rocks, such as limestone, erlan, and quartzite. Acid and coarse weathering rocks are situated at high altitudes.

Climate at the highest altitudes is humid with high amounts of precipitation (approx. 1,250 mm) and with a long period of snow cover (November to beginning of May). At lower altitudes (700 m -950 m) precipitation fluctuates (780 mm - 1350 mm). Average year temperature at the highest altitudes is about 0°C, in lower parts it is about 5°C. The territory of the Krkonoše Mountains is covered by a National Park.

History of Settlement and Management of the Krkonoše Mountains

The first settlement in the Krkonoše Mountains dates back to the 12th and 13th centuries (rather earlier at the Polish side). Colonists (mainly from Germany and Italy) started a period characterised by mineral exploitation. In this period a great proportion of submountain and mountain forests was damaged. In 1609 forest exploitation was substantially reduced. Cattle raising and meadow exploitation became the main source of living. Area of treeless enclaves surrounding mountain abodes and their number have increased. According to Hoser (1804), there were almost 2,500 chalets in the Krkonoše district at the turn of the 19th century.

So-called chalet farming was very important in the 18th and 19th centuries. Most chalets were located in the mountain belt. Nevertheless, communities in the subalpine belt were often used as pastures. It resulted in an important reduction of natural disconnected dwarf pine stands. On the Polish side, settlements were not so dense, and they were concentrated at the foothills due to the less suitable relief (steep slopes).

In the Romantic period, at the turn of the 19th century, tourist activities have started and many chalet owners offered tourist service. Fertilisation of meadows started to stabilise their production. Meadows situated above the timber line were also under pressure (pasture and hay production).

Regular farming continued till the Second World War. The German population was strongly affected by the war and ist consequences: men took part in battles, and most of the population has been resettled into Germany after the war. Few newcomers were interested in farming, and many farms have, thus, ceased to exist. Intensification of agriculture, collectivisation, and punishment of independent farmers even worsened the situation of the mountain meadows: many meadows at high altitudes were abandoned, and meadows at lower altitudes were often transformed into high-productivity units. In the 1980s, owners were obliged to cut their meadows. This duty was cancelled in 1990, but some

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years later the owners realised that cutting is necessary for economic reasons: cut meadows, at least in the close neighbourhood of chalets, create an aesthetic and attractive surrounding, cutting of skiing slopes improves skiing conditions and prolongs skiing season (mainly when there is little snow).

Management of the remaining meadows is rather complicated. There is a poor system of subsidies: money from the Ministry of Agriculture is available for meadow management, but only for farmers breading cattle. Cutting of meadows is also supported by the National Park Authorities. However, there is no use for hay, and money is not enough to enable mountain farms to survive in the strongly competitive economic environment. Thus, the percentage of abandoned meadows is supposed to be increased.

Characteristics of Mountain Meadows

Most of the meadows studied are situated in the montane belt. The grasslands, which arose after the mountain colonisation in the 16th and 17th centuries, are young systems in comparison with meadows at low altitudes. Grasslands form almost continuous chain of treeless areas from the foothills to the alpine areas. Plant cover of the montane meadows is formed partly by species originating in forests; the spatial arrangement leads to the ascend of many plant species to high altitudes and to the descend of originally alpine species to low altitudes. Numbers of locations of some of these originally alpine species are several times higher in these secondary meadows than in the alpine areas, e.g. Viola lutea subsp. sudetica, Campanula bohemica subsp. bohemica, Potentilla aurea, Crepis conyzifolia, etc. This process leads to formation of species-rich communities, which high diversity is even increased by the rise of a number of apomictic endemic types (of hybridogenous origin) mainly of Hieracium subgen. Pilosella.

There are three zones in the framework of the enclaves:

Zone I - close neighbourhood of chalets, so called "grass gardens" - cultivated and intensively manured meadows (see Figure 1) used for hay production (cut 2 times - 3 times per year), dominated by species of Polygono-Trisetion alliance, such as Melandrium rubrum, Ranunculus platanifolius, Festuca rubra, Rumex alpestris, Alopecurus pratensis, Alchemilla sp. div., Poa chaixii, Deschampsia cespitosa, Dactylis glomerata, and by species of alliances Calthion (suballiance Filipendulion), Petasition officinalis and Rumicion alpini, such as Chaerophyllum hirsutum, Cirsium oleraceum, Myrrhis odorata, Angelica sylvestris, Stellaria nemorum. High production and low species diversity are characteristic of these meadows.

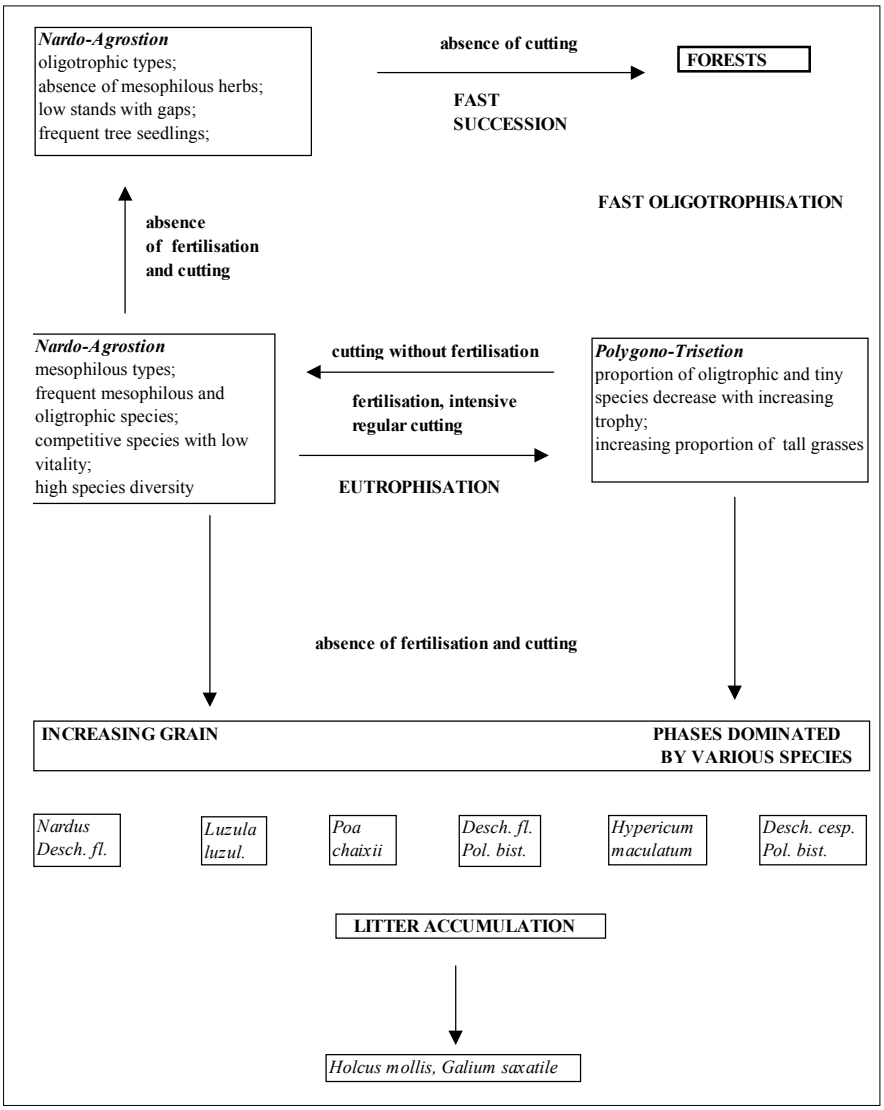

Figure 1: **Relationships between communities of mountain meadows and types of management**

Zone II - central parts of the enclaves; lower eutrophication and cutting than in zone I. The typical management: cutting once a year at the beginning of summer and cattle grazing in the late summer; medium rich, mesotrophic, and slightly oligothophic stands with optimal species composition: alliances Nardion, Nardo-Agrostion tenuis, and Polygono-Trisetion, at low altitudes also Arrhenaterion and Violion.

Zone III - marginal parts of the enclaves used mainly as pastures, cut and fertilised irregularly; acid oligotrophic degradation phases dominated by Nardus stricta, Anthoxanthum odoratum, Silene vulgaris, Galium saxatile, Vaccinium spp., Deschampsia flexuosa, Holcus molis, Calamagrostis villosa (alliances Nardion, Nardo-Agrostion tenuis, Violion caninae).

For the complete list of plant communites distinguished in the montane grasslands see *Table 1*.

Artificial meadows are valuable for the following reasons:

Table 1: **Survey of plant communities distinguished in the Krkonoše Mountains**

SURVEY OF PLANT COMMUNITIES DISTINGUISHED

MOLINIO-ARRHENATHERETEA TÜXEN 1937

MOLINIETALIA KOCH 1926

Calthion TÜXEN 1937 em. LEBRUN et al. 1949

Calthenion BALÁTOVÁ-TULÁCKOVÁ 1978

Chaerophyllo hirsuti-Calthetum (BUTTLER, CORNALI et RICHARD 1983)

BALÁTOVÁ-TULÁCKOVÁ 1985
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1997
Chaerophyllo hirsuti-Crepidetum paludosae BALÁTOVÁ-TULÁCKOVÁ in BALÁTOVÁ-TULÁCKOVÁ et Venanzoni 1990
subas. *caricetosum canescentis* BALÁTOVÁ-TULÁCKOVÁ 1997
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1997
subas. *typicum* BALÁTOVÁ-TULÁCKOVÁ 1997

Scirpetum sylvatici RA£SKI 1931
subas. *caricetosum fuscae* KNAPP 1945 em. BALÁTOVÁ-TULÁCKOVÁ 1981
subas. *caricetosum gracilis* BALÁTOVÁ-TULÁCKOVÁ 1993
subas. *chaerophylletosum hirsuti* BALÁTOVÁ-TULÁCKOVÁ et ONDRÁCKOVÁ 1993

Scirpo-Juncetum filiformis OBERDORFER 1957
subas. *typicum* BALÁTOVÁ-TULÁCKOVÁ 1991

Polygono-Cirsietum palustris BALÁTOVÁ-TULÁCKOVÁ 1974
subas. *violetosum palustris* BALÁTOVÁ-TULÁCKOVÁ 1974
subas. *chaerophylletosum hirsuti* BALÁTOVÁ-TULÁCKOVÁ 1997
subas. *typicum* BALÁTOVÁ-TULÁCKOVÁ 1974
subas. *molinietosum caerulae* BALÁTOVÁ-TULÁCKOVÁ 1974
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1983

Polygono-Cirsietum heterophylli BALÁTOVÁ-TULÁCKOVÁ 1975
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1975
subas. *chaerophylletosum hirsuti* BALÁTOVÁ-TULÁCKOVÁ 1997

Junco filiformis-Polygonetum bistortae BALÁTOVÁ-TULÁCKOVÁ 1981
subas. *typicum* BALÁTOVÁ-TULÁCKOVÁ 1983

Angelico-Cirsietum oleracei TÜXEN 1937
subas. *caricetosum fuscae* TÜXEN 1937
subas. *caricetosum cespitosae* BALÁTOVÁ-TULÁCKOVÁ 1981
subas. *caricetosum gracilis* ELLENBERG 1952
subas. *chaerophylletosum hirsuti* BALÁTOVÁ-TULÁCKOVÁ 1993
subas. *molinietosum coeruleae* BALÁTOVÁ-TULÁCKOVÁ 1981
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1983

Cirsietum rivularis NOWIÑSKI 1927
subas. *caricetosum gracilis* BALÁTOVÁ-TULÁCKOVÁ in RYBNÍÈEK et al. 1984
subas. *typicum* BALÁTOVÁ-TULÁCKOVÁ 1977

Filipendulenion (LOHMEYER in OBERDORFER 1967) BALÁTOVÁ-TULÁCKOVÁ 1978

Filipendulo-Epilobietum hirsuti SOUGNEZ 1957

Chaerophyllo hirsuti-Filipenduletum NIEMANN, HEINRICH et HILBIG 1973
subas. *chrysosplenietosum alternifolii* BALÁTOVÁ-TULÁCKOVÁ 1984
subas. *violetosum palustris* BALÁTOVÁ-TULÁCKOVÁ 1979
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1997
subas. *typicum* (NEUHÄUSL et NEUHÄUSLOVÁ-NOVOTNÁ 1975), BALÁTOVÁ-TULÁCKOVÁ 1985

Cirsio heterophylli-Filipenduletum NEUHÄUSL et NEUHÄUSLOVÁ-NOVOTNÁ 1975
subas. *geranietosum sylvatici* BALÁTOVÁ-TULÁCKOVÁ 1997

ARRHENATHERETALIA TÜXEN 1931

Arrhenatherion KOCH 1926

Arrhenatheretum elatioris J. BRAUN 1915

Poo-Trisetetum KNAPP 1951

Trifolio-Festucetum rubrae OBERDORFER 1957
subas. *alopecuretosum* NEUHÄUSL 1972
subas. *carlinetosum* NEUHÄUSL 1972

Polygono-Trisetion BR.-BL. et TÜXEN ex MARSCHALL 1947 nom. invers.

Geranio-Trisetetum KNAPP 1951
subas. *lathyretosum pratensis* BLAZKOVÁ 1997
subas. *pimpinelletosum saxifragae* BLAZKOVÁ 1997
subas. *nardetosum* BLAZKOVÁ 1997
subas. *melandrietosum* BLAZKOVÁ 1997
subas. *bellidetosum* BLAZKOVÁ 1997

Melandrio-Phleetum alpini BLAZKOVÁ 1997
subas. *alopecuretosum* BLAZKOVÁ 1997
subas. *nardetosum* BLAZKOVÁ 1997
subas. *violetosum luteae* BLAZKOVÁ 1997

Cynosurion TÜXEN 1947

Lolio-Cynosuretum TÜXEN 1937

Caro-Poetum BLAZKOVÁ 1973

NARDO-CALLUNETEA PREISING 1949

NARDETALIA PREISING 1949

Violion caninae SCHWICKERATH 1944

Thymo-Festucetum ovinae OBERDORFER et GÖRS in GÖRS 1968

Nardo-Festucetum capillatae KLIKA et ŠMARDA 1944

Nardo-Agrostion tenuis SILLINGER 1933

Sileno vulgaris-Nardetum KRAHULEC 1990
subas. *crepidetosum* KRAHULEC 1997
subas. *galietosum* KRAHULEC 1997
subas. *carlinetosum acaulis* KRAHULEC 1997
subas. *typicum* KRAHULEC 1997
subas. *pleurozietosum* KRAHULEC 1997
degradation phases

Polygono-Deschampsietum flexuosae BLAZKOVÁ in KRAHULEC 1990
subas. *campanuletosum rotundifoliae* BLAZKOVÁ 1997
subas. *poetosum chaixii* BLAZKOVÁ 1997
subas. *calamagrostietosum* BLAZKOVÁ 1997

Nardion BR.-BL. 1926
Thesio alpini-Nardetum JENÍK, BUREŠ et BUREŠOVÁ 1980
subas. *campanuletosum bohemicae* ŠTURSOVÁ et ŠTURSA 1983
subas. *phleetosum alpini* KRAHULEC 1997

Solidagini-Nardetum KRAHULEC 1997
subas. *silenetosum vulgaris* KRAHULEC 1997
subas. *hypochoeridetosum uniflorae* KRAHULEC 1997
subas. *callunetosum* KRAHULEC 1997

CALLUNO-ULICETALIA TÜXEN 1937

Genistion Böcher 1943

Arnico montanae-Callunetum SCHUBERT 1960

Calluno-Vaccinietum BÜKER 1942

JUNCETEA TRIFIDI HADAC in KLIKA et HADAC 1944

CARICETALIA CURVULAE BR.-BL. in BRAUN-BLANQUET et JENNY 1926

Nardo-Caricion rigidae NORDHAGEN 1937

Carici fyllae-Nardetum (ZLATNÍK 1928) JENÍK 1961
subas. *typicum* BERCIKOVÁ 1976
subas. *deschampsietosum cespitosae* KRAHULEC 1997

FURTHER COMMUNITIES UNDER STUDY

Scheuchzerio-Caricetea fuscae

Caricetalia fuscae - PhD thesis (D. Abazid)

Poo chaixii-Deschampsion cespitosae + connected communities
with *Deschampsia cespitosa* in the supramontane belt of the Krkonoše Mts.
- PhD thesis (M. Fabšièová)

degradation phases dominated by species except *Polygonum bistorta*
management dF with *Poa chaixii* (diploma thesis of M. Lexa)

❶ They are important from the point of view of biodiversity: particularly grasslands dependent on traditional management (cutting, grazing, rare and/or irregular fertilisation) are extremely species-rich, especially with respect to the species number concentrated on scales of tens and hundreds of square centimetres; about half of all native species of the whole mountain range occur within meadows, including some young endemics (about 450 species of vascular plants).
❷ The exists a substantial part ofthe cultural heritage and the recreation potential of the landscape (nice views of the landscape, skiing), and, for that reason they are economically important.
❸ Aesthetic value of the meadows; they form a nice surrounding of mountain chaletsand provide nice views into the country.

Table 2: **The meadow dynamic in relation to management**

1. poor soils	cutting	decreased diversity; oligotrophisation
	cutting + fertilisation	**increased diversity**
	absence of cutting	dP (*Deschampsia flexuosa*); succession towards forests; decreased diversity
2. slight and medium nutrient supply	cutting	decreased diversity; oligotrophisation
	cutting + fertilisation	**stabilised or increased diversity**
	absence of cutting	dP (*Polygonum bistorta*); decreased diversity
3. medium and high nutrient supply	**cutting**	decreased nutrient level; **increased diversity**
	cutting + fertilisation	stabilised or decreased diversity
	absence of cutting	dP (*Polygonum bistorta*); decreased diversity
4. high nutrient supply	**cutting**	**slow increase of diversity** (rate dependent on the soil)
	cutting + fertilisation	stabilised or decreased diversity
	absence of cutting	dP with tall herbs (*Filipendula, Urtica, Chaerophylum aromaticum, Myrrhis odor., Rumex alpinus*); decreased diversity

dP: degradation phase of a meadow characterised by dominance of one or two species, and by a low number of species

Management Problems

Most mountin meadows are artificial (anthropogenous) systems, dependent on cutting and/or grazing and fertilisation. The species composition of grasslands is very sensitive to small changes of management.

Large areas, difficult management (limited use of mechanisation) and low accessibility of secondary mountain meadows in the Krkonoše Mountains as well as big socio-economic changes mainly after the Second World War (resettlement of population, intensification of agriculture, increasing living standards, collectivisation and punishment of independent farmers) led to abandonment, and thus, to big problems in nature conservation. Similar to other European countries, problems are connected with changes in meadow management due to decreased demands for hay production. Strong economic pressure during the last years caused the abandonment of many farms. Existing farms have to face serious problems endangering their survival. Absence of management lasting even for several decades has led to extensive degradation of meadows. These systems may develop quickly into forest or into long term and relatively stable degradation stages dominated usually by one or two species (Polygonum bistorta, Deschampsia cespitosa, Poa chaixii, Holcus mollis, Luzula luzuloides, Nardus stricta, Deschampsia flexuosa, Hypericum maculatum, Galium saxatile) (Figure 1). The course of development of a community as well as the course of its degradation is determined by the soil type (nutrient supply), type of management as well as by local environmental conditions (*Table 2*). It means that the same management results in different processes in soils with different nutrient levels. Ways to stabilise or increase species diversity of meadows are, thus, different in different locations.

The main problem connected with degradation phases is that the introduction of the original management does not lead to the reformation of the original communities present in the location before abandonment.

Management by cutting is difficult mainly at higher altitudes. For that reason, grazing management is a reasonable alternative. However, regular cow grazing was done only after the first cut; sheep grazing was absent. Thus, there was no experience with sheep grazing, and conservation authorities were afraid of its negative influence. We started a study of sheep grazing to evaluate possible risks.

The influence of grazing was studied in two experiments:

(i) the vegetation succession after the end of grazing carried out in 1986-1990 (Pátková et Krahulec 1997);

(ii) the succession after the introduction of grazing to another location (Krahulec et al 1994, Krahulec et al 1997, Bílek et al 1998).

The results showed that there were fast changes following the end of grazing as well as its introduction; there were no risks for the rare and protected species provided that the number of sheep corresponds to the amount of biomass produced. Biomass estimation is difficult due to big year-to-year fluctuations caused by climatic conditions. For that reason, the combination of medium-intensity grazing followed by cutting seems to be the best alternative management.

One of the degradation phases dominated by Polygonum bistorta (classified as associations Polygono-Deschampsietum a Junco-Polygonetum) has reached remarkable spread. For that reason, the study of nitrogen turnover was started. Polygonum bistorta functions as a nutrient sink, especially for nitrogen. Growth of the other species is, thus, limited by its shortage. Cutting of such meadows leads to impoverishment of the entire system, and species-poor communities dominated by Deschampsia flexuosa are

being formed. The species-rich communities may be formed by a combination of cutting and fertilisation. The influence of introduction of grazing is the same: suppression of grazed Polygonum bistorta and input of nutrients available for other species by excrement.

Literature - Management Studies

Bílek, M., Záková, I. et F. Krahulec 1998: Louky Krkonoš. Alternativa obhospodarování - pastva ovcí. (Meadows in the Krkonoše Mts.: alternative management - sheep grazing), Ochrana Prírody 53/6: 167-170.

Hadincová, V., Herben, T., Kovárová, M., Krahulec, F. et S. Pecháckova 1998: Zmìny v produkci jednotlivých druhù krkonošských luk v prùbìhu deseti let. (Fine scale changes in production of individual species in the Krkonoše Mts. during ten years), Opera Corcont. 34 (1997): 59-77.

Herben, T., Krahulec, F., Hadincová, V. et S. Pecháckova 1995: Climatic variability and grassland community composition over 10 years: separating effects on module biomass and number of modules. Funct. Ecol. 9: 767-773.

Kettnerová, S., Krahulec, F., Pátková, R., Hadincová, V. et T. Herben 1995: Moznosti managementu opuštìných luk v Krkonoších. (Management of abandoned meadows in the Krkonoše Mts.), Zpr. Ces. Bot. Spolec. 30, Mater. 12: 144-148.

Krahulec, F. 1993: Vyuzití pastvy ovcí v managementu lucních ekosystémù chránìných území. (Sheep grazing management of mountain meadows in protected areas), Ovcí noviny, Rada Svazu chovatelù ovcí a koz v Cechách, Praha 4: 2-5.

Krahulec, F., Hadincová, V., Herben, T., et S. Kettnerová 1994: Monitorování vlivu pastvy ovcí na rostlinná spolecenstva: Zadní Renerovky v Krkonošském národním parku. (Vegetation changes under sheep grazing in the Krkonoše National Park) - Príroda, Praha, 1: 191-196.

Krahulec, F., Herben, T., Hadincová, V., Kettnerová S. et M. Kovárová 1994: Sledování trvalých ploch v lucních porostech Krkonoš. (Ten years of permanent plot studies in the Krkonoše Mts.) Príroda, Praha, 1: 23-30.

Krahule, F. 1994: Pastva ovcí v chránených územích.(Sheep grazing in protected areas), Náš chov 54/9: 36.

Krahulec, F., Pecháckova, S., Hadincová, V. et T. Herben 1996: Výzkum montánních luk Krkonoš: prehled problematiky. (Research of mountain meadows of the Krkonoše Mts.: problem presentation). In: Vacek S. (ed.), Monitoring, výzkum a management ekosystémù na území Krkonošského národního parku, s. 313-320.

Krahule, F., Blazková, D., Balátová-Tulácková, E., Štursa, J., Pecháckova, S. et M. Fabšicová 1997: Louky Krkonoš: rostlinná spolecenstva a jejich dynamika. (Meadows in the Krkonoše Mts.: plant communities and their dynamics), Opera Corcont. 33: 33-250 + Príloha.

Krahulec, F. 1998: Louky Krkonoš: vztah variability a rízeného usmernování vývoje. (Meadows in the Krkonoše Mts.: relationships between their variability and managed development) Ochrana Prírody 53/4: 103-106.

Pátková, R. et F. Krahulec 1998: Sukcese lucní vegetace v Krkonoších po skoncení pastvy ovcí. (Succession in a mountain meadow after the stopping of sheep grazing), Opera Corcont. 34 (1997): 91-104. (1998).

Pecháckova, S. et F. Krahulec 1995: Efficient nitrogen economy: key to the success of Polygonum bistorta in an abandoned mountain meadow. Folia Geobot. Phytotax. 30: 211-222.

Pecháckova, S. et F. Krahulec 1998: Louky Krkonoš: obnova luk s prevahou rdesna hadího korene (Polygonum bistorta). (Meadows in the Krkonoše Mts.: restoration of meadows dominated by Polygonum bistorta), Ochrana Prírody 53: 136-137.