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Ecological restoration above the timberline: Demographic monitoring of whole trial plots in the Swiss Alps

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Abstract

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Five and six years old restoration plots in a machine-graded downhill ski run at ca. 2500 m a. s. l., were monitored during a three-year period to assess in a mid-term the success of ecological restoration. The demographic monitoring involved censuses of whole mixed stands.

The study revealed that transplant losses mostly occurred between the third and the fifth year after restoration. Transplant mortality in later years was generally low, but ski run maintenance machines may apparently damage or destroy some sectors also in older plots. Mean survival rates calculated for 1992–1994 in comparison to the beginning of the restoration are 67.5–76.4% in plots MG1 and MG2 restored in 1986, and 52.6–59.7% in plots MG3 and MG4 restored one year later.

Principal demographic features of the studied plots were (a) consistent occurrence of the full range of age-state classes and (b) pronounced rejuvenation of all plot communities. These aspects indicate an ongoing development of plant cover resulting from reproduction of transplants and also an extensive immigration of diaspores with subsequent development of new populations.

Transplantations on a local scale and provision of safe-sites by use of biodegradable materials are considered indispensable elements in ecological restoration of machine-graded alpine ski runs. Demographic monitoring of whole plots seems to be very useful to midterm assessment of the restoration success.

Key words: Ecological restoration, high-alpine ski runs, transplantation, monitoring, census.

Introduction

Demographic studies and, in particular, demographic monitoring with repeated data collection over time as an essential component, are indispensable to proper evaluations in conservation biology and ecological restoration. It seems, however, that both the "census" and the "monitoring" terms are sometimes used in a slightly different sense.

The original term "census" goes back to the time of the Roman Empire and refers to count of Roman citizens repeated every five years. It has been used ever since to evaluate e.g. age structure of human population in various countries. The censuses distinctly focus on population groups and fates of individuals are not followed. Census in conservation biology, on the other hand, is usually understood as a count of tagged or precisely located organisms. As far as plants are concerned, problems related to marking of individuals and population mapping are well-known; units representing *sub-individual* level of biological organization are frequently chosen to record for demographic studies (Hutchings 1986, 1991).

While biological conservation is primarily dealing with preservation of still existing populations, the main aim of ecological restoration is reintroduction of community as a whole with the resulting build-up of biodiversity. Demographic studies may accordingly involve not only individuals within single populations but also levels of biological organization *higher than individuals*, e.g. whole community as a unit (Urbanska, in press).

A similar difference concerns the monitoring. Most authors working in conservation biology study single species and agree that the term "monitoring" should apply to studies involving censuses with marked individuals which permit to follow their fates (e.g. Davy and Jefferies 1981, Bradshaw 1981, Hutchings 1990, 1991, Pavlik and Barbour 1988). While the fates of individuals and single populations undoubtedly influence the post-restoration status of a community, it may be performance of the community as a whole which permits a restored ecosystem to withstand damage. Hence the need for demographic monitoring of mixed stands.

The question as to which purposes the census data should be used is not always answered in the same way. As far as biological conservation is concerned, some authors, e.g. White and Bratton (1981), point out that the census data convey information useful for judging management success, but some other scientists argue that data concerning e.g. recruitment or reproduction by seed are relevant to conservation *planning* rather than to the actual assessment of the results (see the review by Hutchings 1991). In ecological restoration, census data undoubtedly are important to the assessment of restoration *success*; they also indicate a further developmental potential of the reintroduced community, possible ways of aftercare, etc.

The present paper deals with demographic monitoring of restoration plots above the timberline. I argued elsewhere (e.g. Urbanska 1989, Urbanska and Hasler 1992, Urbanska in press) that ecological restoration seems to be the only long-term solution as far as environmental damage in high-alpine sites is concerned. The assessment of restoration above the timberline esp. in the first decade after the work has been completed, should be based on demographic studies since the traditional phytosociological releves do not provide a satisfactory information on early dynamics of populations or whole stands. I intend to show here the usefullness of a whole plot monitoring for mid-term assessment of ecological restoration in extreme conditions of high-alpine vegetation belt. The second paper of this series, now in preparation, will focuse on performance of single populations.

Research area, study objects and methods

General characteristic of the study area

The research area is situated within the alpine belt near Davos, Grisons, NE Swiss Alps. The present papers deals with trials carried out on siliceous substratum. The plots are installed on a machine-graded downhill ski run at SW slope of Jakobshorn, at altitude of ca. 2500 m a.s.l. (Figs. 1–2).

The climatic conditions in the study area are rather severe (Hasler 1992) and snowfall or intermittent frost may occur at any time throughout the summer. An average growth period includes ca. 14 weeks.

The ski run has been machine-graded in 1970. The extant indigenous vegetation was then removed and discarded so that the bare graded slope has been exposed to erosion with the resulting washout of fine soil. Until to-day there are no soil horizons developed and the skelett content of the soil is high, particularly within the uppermost 40 cm; nutrient content is very low (Flüeler 1992).

Since the ski area of Jakobshorn is served in winter by two cable-cars and three skilifts, many skiers pass over our trial plots day after day during ca. four months. The trampling effect is reinforced by numerous ski classes which use this particular area as practising slope. The damage to the alpine environment is made worse by the daily use of ski run maintenance machines which alter the now cover structure and often leave track prints all over the area esp. at times when snow begins to melt.

The alpine slopes of Jakobshorn are extensively grazed in summer by cattle, marmots, and partly also by snow grouse (*Lagopus mutus*). Herbivores not only graze leaves and/or flowers but also dig for roots. Considerably damaged vegetative parts, destroyed reproductive structures, trampling, and also partly denuded tap roots represent characteristic herbivore damage observed every year in our trial plots.

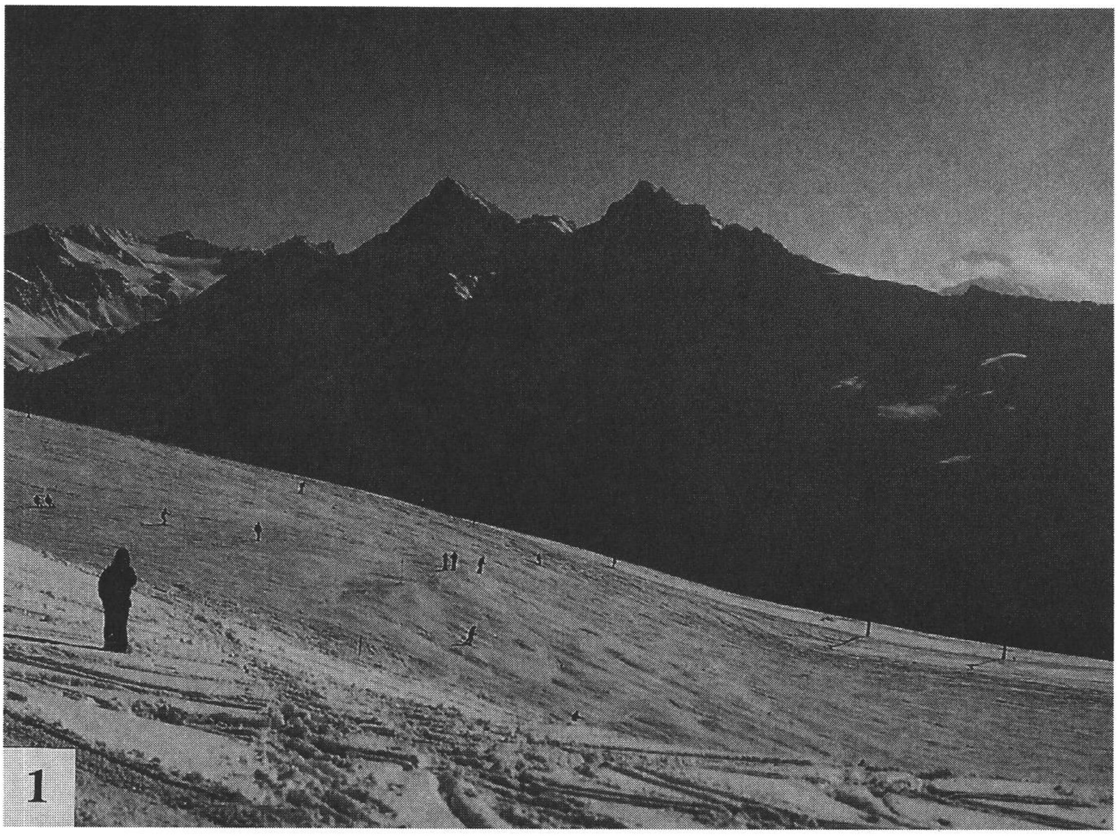
Restoration trials

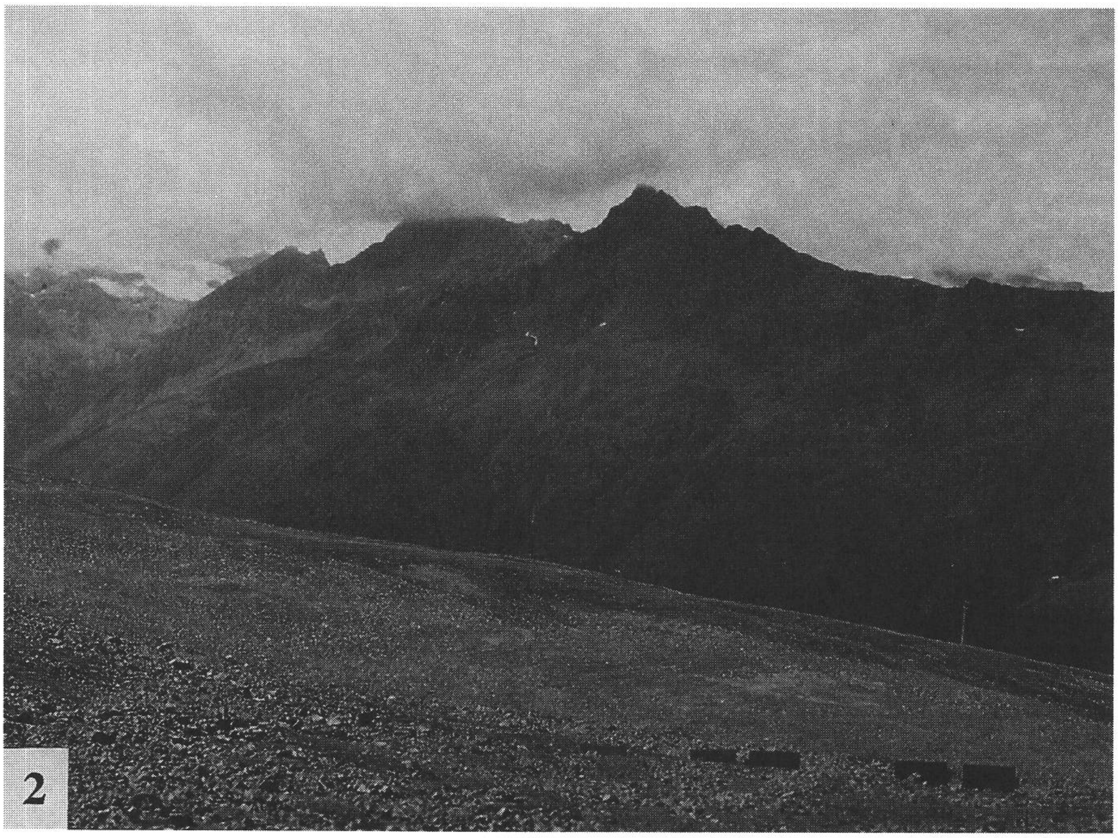
The plots were set up respectively in 1986 and 1987. They mostly consisted of clonal transplants; grasses, other graminoids, legumes and forbs were used in various combinations (Table 1).

Transplants were obtained by single-ramet cloning (SRC) of donor plants originating from natural sites. They were grown in garden soil prior to the restoration.

The planting was done according to a precise design used in all our trials (e.g. Urbanska et al. 1987), an average density being 40 transplants per m^2. Plot sectors consisted of small single-species neighbourhoods. The restoration work at the site did not include any soil manipulations. After planting, plots were covered with the biodegradable CURLEX® wood-fiber mat to provide safe-site conditions. No further measures were untertaken to protect the plots from damage by skiers, ski run maintenance machines, or herbivores.

Plots were of various length because of larger rock groups irregularly distributed over the ski run which interfered with the planting design. The longest plot MG1 measured 12 m, plot MG2 – 8.8 m, plot MG3 – 8 m and plot MG4 – 9.6 m. The length differences among the plots obviously led to differences in the initial number of the transplants (Table 4). All plots were of the same width (0.94 m).





Figs. 1–2. Study area on a downhill ski run at SW slope of Jakobshorn near Davos (Grisons, NE Swiss Alps), ca. 2500 m a.s.l. 1. The machine-graded ski run in winter. 2. The same site in summer: the studied restoration plots are situated in the middle part.

Tab. 1. Current species composition. Included are all species used initally as transplants and all immigrant species identified so far.

Species used in restoration	Immigrant species (1994)
(a) plot MG1	
Agrostis schraderiana	*Agrostis rupestris*
Chrysanthemum alpinum	*Campanula scheuchzeri*
Elyna myosuroides	*Cardamine resedifolia*
Hieracium pilosella	*Chrysanthemum alpinum**
Poa laxa	*Deschampsia flexuosa*
Trifolium nivale	*Gnaphalium supinum*
Trifolium repens	*Hieracium alpinum*
	Homogyne alpina
	Leontodon helveticus
	Salix herbacea
	Sedum alpestre
	Senecio carniolicus
(b) plot MG2	
Agrostis schraderiana	*Arenaria biflora*
Carex curvula	*Cardamine resedifolia*
Carex sempervirens	*Chrysanthemum alpinum**
Chrysanthemum alpinum	*Leontodon helveticus*
Doronicum clusii	*Saxifraga bryoides*
Hieracium pilosella	*Sedum alpestre*
Luzula lutea	
Poa laxa	
(c) plot MG3	
Agrostis schraderiana	*Agrostis rupestris*
Chrysanthemum alpinum	*Arenaria biflora*
Poa laxa	*Cardamine resedifolia*
Doronicum clusii	*Chrysanthemum alpinum**
Carex curvula	*Gentiana* spp.
Luzula lutea	*Gnaphalium supinum*
Hieracium pilosella	*Leontodon helveticus*
	Ranunculus grenierianus
	Senecio carniolicus
(d) plot MG4	
Agrostis schraderiana	*Agrostis rupestris*
Biscutella levigata	*Anthoxanthum alpinum*
Carex curvula	*Cardamine resedifolia*
Carex sempervirens	*Chrysanthemum alpinum**
Chrysanthemum alpinum	*Festuca rubra*
Doronicum clusii	*Gnaphalium supinum*
Elyna myosuroides	*Leontodon helveticus*
Hieracium pilosella	*Ranunculus grenierianus*
Luzula lutea	*Senecio carniolicus*
Poa laxa	*Veronica bellidioides*
Trifolium nivale	
Trifolium repens	

* *Ch. alpinum* was used as transplant material but it also immigrated spontaneously into the plot from neighbouring areas.

Censuses

Detailed censuses were done from 1992 through 1994 once a year at approximately the same date in the middle of the growing period. The studies were carried out with a light-metal frame of 1 m^2 subdivided into one hundred smaller squares. The fixed point-monitoring permitted to identify transplants during each census but no plants were tagged. Newcomers were not followed individually, but notes on their distribution within subsquares were taken.

Plants belonging to various age-state classes were counted within each of the hundred sub-squares and then totalled respectively for each sector and each whole plot. The classes were defined and codified as follows:

seedlings (*s*)	= plantlets with a single leaf in monocots and with green cotyledons in dicots;
juveniles (*y*)	= young plants with more than one leaf in monocots and without functional cotyledons in dicots. This class included the largest number of plants which represented different developmental stages and were of different sizes.
non-reproducing newcomers (*nr*)	= adults without flowers or fruits/seeds
reproducing newcomers (*r*)	= adults with reproducing structures
non-reproducing transplants (*NR*)	= transplants without reproductive structures
reproducing transplants (*R*)	= transplants with reproductive structures
dead transplants (*D*)	= plants dead but still recognizable as units.

Early post-restoration data

Observations on the plots carried out during the first three years after restoration focused on survival and onset of flowering in transplants (Gasser 1989). Survival in the second year after restoration proved to be very good and transplants of some species flowered copiously at that time (Fig. 3).

Results

The numbers of plants registered during the present study should be considered as minimum counts since the Curlex mats were not completely degraded in some spots so that small seedlings and/or juveniles might have been overlooked. Transplants were easily identified for the most part, except for *Agrostis schraderiana* which formed medium-sized loose stands. Since clonal growth in this grass species corresponds to the "guerrilla-type", the actual area of the originally planted units could not have been always defined and a few more transplants might have been mistakenly recorded. It should be stressed, however, that the possible faults in the transplant count do not exceed ca. ten units in the whole study.

Total number of plants recorded

Total number of plants recorded during the censuses differed considerably from plot to plot (Table 2). There were also substantial differences among sectors and subsectors of a given sector (Table 3). The numbers of transplants installed at the beginning of the restoration trial varied in function of the plot length (Table 4); it seems, however, that

Tab. 2. Annual changes in number and distribution of age-state variants within one sector (1 m^2) exemplified by sector A of plot **MG1**. sMo = monocot seedlings; sDi = dicot seedlings; yMo = juvenile monocots; yDi = juvenile dicots; nrMo = non-reproducing monocots; nrDi = non-reproducing dicots; rMo = reproducing monocots; rDi = reproducing dicots; NR = non-reproducing transplants; R = reproducing transplants; D = dead but still identifable transplants.

Year	sMo	sDi	yMo	yDi	nrMo	nrDi	rMo	rDi	NR	R	D	Total
1992	6	91	1	18	0	6	0	8	30	28	0	188
1993	188	82	47	144	0	16	0	11	39	19	0	546
1994	437	58	41	219	4	19	0	19	24	33	1	855

Tab. 3. Annual changes in total number of age-state variants in the studied plots throughout the three-year monitoring period. For detailed explanations see Table 2.

Year	sMo	sDi	yMo	yDi	nrMo	nrDi	rMo	rDi	NR	R	D	Total
(a) plot MG1												
1992	42	1079	49	344	4	61	2	110	214	120	0	2025
1993	686	1159	317	1817	37	232	1	113	199	123	12	4696
1994	982	140	217	1226	22	134	4	170	149	144	27	3215
(b) plot MG2												
1992	121	304	29	119	2	25	1	18	211	111	18	959
1993	1540	639	228	664	6	72	1	36	182	105	35	3508
1994	616	23	57	386	2	49	3	38	188	164	5	1461
(c) plot MG3												
1992	18	133	6	34	0	4	4	20	221	93	1	534
1993	42	1	47	87	1	36	0	25	211	94	9	553
1994	76	3	12	97	3	27	7	25	135	163	7	555
(d) plot MG4												
1992	12	99	12	55	7	18	3	47	213	84	6	556
1993	10	27	46	102	12	46	0	22	185	93	19	562
1994	10	9	15	177	22	77	8	22	160	108	10	618

Tab. 4. Transplant survival in the studied plots in the first year of monitoring. ITN = number of transplants used initially in the restoration trials NLT 1992 = number of live transplants recorded during the first census. S% = survival after five or six years.

Plot code	Restoration year	ITN	NLT 1992	S%
MG1	1986	602	334	55.5
MG2	1986	440	322	73.4
MG3	1987	400	314	78.5
MG4	1987	471	297	63.0

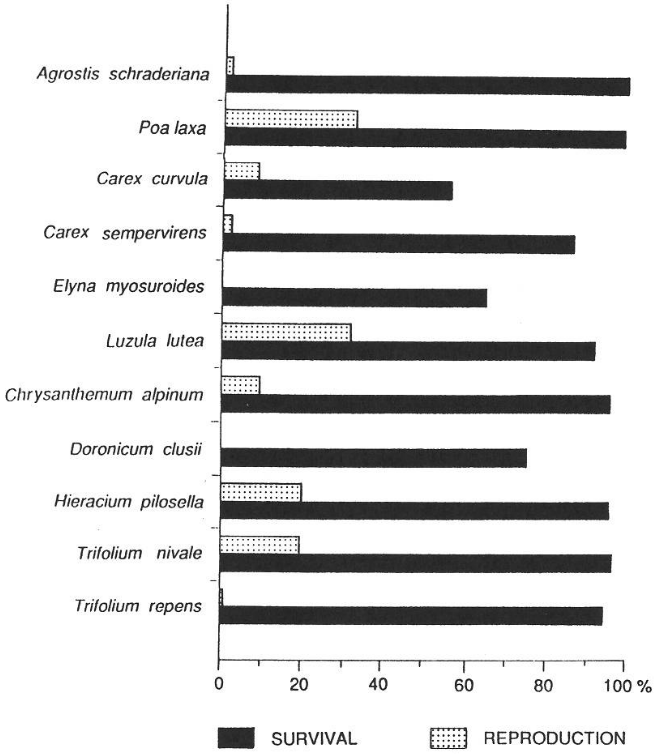


Fig. 3. Survival and reproduction of clonal transplants in the studied plots recorded in the second year after restoration. After data from Gasser (1989), modified.

the total community size registered during the censuses was influenced only partially by these initial differences.

While plots MG1 and MG2 set up in 1986 were characterized by strong annual fluctuations in the total number of the plants recorded, plots MG3 and MG4 installed one year later were rather stable in this respect. The exceedingly strong increase in community size noted in 1992 in plots MG1 and MG2 was followed by considerable reduction in the subsequent year. Contrary to this pattern, community size fluctuations were negligible in plot MG3, and a slight increase in plot MG4 occurred only once throughout the study period (Table 2).

Behaviour of transplants

Survival

The number of live transplants recorded in the first year of the present study indicated that most deaths in this group apparently occurred between the third and the fifth year after restoration; losses to the plot communities ranged from 21.5% in plot MG3 to 44.5% in plot MG1 (Table 5). On the other hand, the mortality of transplants recorded throughout the three study years 1992–1994 i.e. from five years after restoration onwards, was rather low (4–9%, Table 3). Dead transplants were observed mostly in 1992 except for plot MG1 in which as many as 27 dead clonal units were recorded in 1994 (Table 2) along with an extensive plot damage caused by ski run maintenance machines.

The mean survival percentages in plots ranged from 52.6% in plot MG1 to 76.4% in plot MG3, the corresponding values in plot MG2 and MG4 being 67.5% and 59.7%, respectively (Fig. 4).

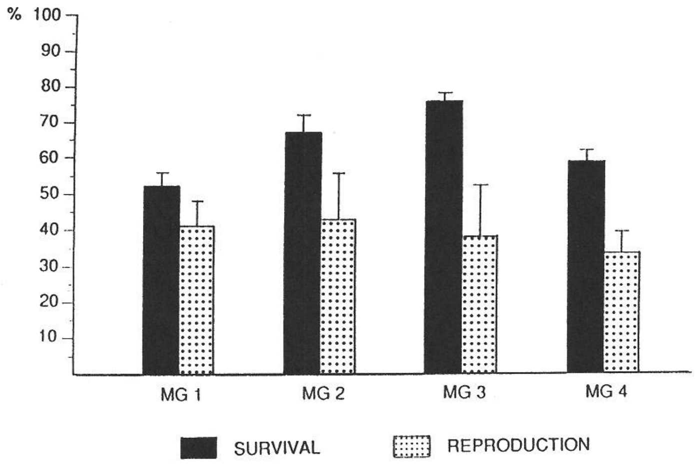


Fig. 4. Survival and reproduction of clonal transplants in the studied plots: mean values of three study years (1992–1994). Single bars refer to standard deviation.

Tab. 5. Annual fluctuations in survival (S) and reproduction by seed (R) of transplants in the studied plots. Survival percentages were calculated from the initial transplant number and refer to live transplants recorded at each census. Flowering percentages were calculated from the total number of live transplants present at each census.

Plot code	**1992**		**1993**		**1994**	
	S (%)	R (%)	S (%)	R (%)	S (%)	R (%)
MG1	55.5	35.9	53.5	38.2	48.7	49.1
MG2	73.2	34.5	65.2	36.6	64.1	58.2
MG3	78.5	29.6	76.3	30.8	74.5	54.7
MG4	63.1	28.3	59.0	33.4	56.9	40.3

Reproduction by seed

The number of reproducing transplants increased in all plots throughout the study period (Table 2). The temporal pattern of that increase was, however, not consistent (Table 5): compared to 1992, only ca. 2% more reproducing transplants were recorded next year in three plots, and the increase in the best performing plot MG4 did not exceed 5 per cent. On the other hand, the corresponding changes between 1993 and 1994 were much more substantial and ranged from 6.9% in plot MG4 to 23.9% in plot MG3.

Mean percentages of reproducing transplants calculated from three study years were roughly comparable in plots MG1, MG2, and MG3 (38.7–43.1%); on the other hand, plot MG4 damaged by herbivores feeding on late-flowering forbs was characterized by only 34% (Fig. 4).

Immigration

On the whole, 19 immigrant species were recorded so far in the studied plots (Table 1). They largely differed from each other as to population size and age-state structure; it is likely that some species are already represented in the plots by several generations

Tab. 6. Annual changes in age-state structure (%) of the studied plots. For detailed explanations see Table 2.

Year	sMo	sDi	yMo	yDi	nrMo	nrDi	nrMo	rDi	NR	R	D
(a) plot MG1											
1992	2.1	53.3	2.4	17.0	0.2	3.0	0.1	5.4	10.6	5.9	0.0
1993	14.6	24.7	6.8	38.7	0.8	4.9	0.0	2.4	4.2	2.6	0.3
1994	30.5	4.4	6.8	38.1	0.7	4.2	0.1	5.3	4.6	4.5	0.8
(b) plot MG2											
1992	12.6	31.7	3.0	12.4	0.2	2.6	0.1	1.9	22.9	11.6	1.9
1993	43.9	18.2	6.5	18.9	0.2	2.1	0.0	1.0	5.2	3.0	1.0
1994	42.2	1.6	3.9	26.4	0.1	3.4	0.2	2.6	8.1	11.2	0.3
(c) plot MG3											
1992	3.4	24.9	1.1	6.4	0.0	0.7	0.7	3.8	41.4	17.4	0.2
1993	7.6	0.2	8.5	15.7	0.2	6.5	0.0	4.5	38.2	17.0	1.6
1994	13.7	0.5	2.2	17.5	0.5	4.9	1.3	4.5	24.3	29.3	1.3
(d) plot MG4											
1992	2.3	19.1	2.3	10.6	1.3	3.5	0.6	9.0	33.9	16.2	1.2
1993	1.8	4.8	8.2	18.1	2.1	8.2	0.0	3.9	32.9	16.5	3.4
1994	1.6	1.4	2.4	28.6	3.6	12.5	1.3	3.6	25.9	17.5	1.6

whereas the others are recent arrivals. Curiously enough, some immigrants represent later seral stages. My previous studies dealing with estimation of a nearest possible diaspore source (Urbanska, in press) suggest that the immigrant diaspores may originate partly from the nearby intact vegetation and partly from other restoration plots installed on the same ski run. Reproducing individuals were observed so far in about a half of the immigrant species but their number greatly varied among species.

Age-state structure of the plot communities

In spite of considerable size variation among age-state classes, some developmental trends were unmistakable. The principal demographic features may be described as follows:

- full range of age-state classes;
- pronounced rejuvenation of the plot communities.

Annual fluctuations notwithstanding, newcomers in plots were represented mostly by seedlings and juveniles (Tables 2–3). The characteristic age-state structure of the communities inhabiting the plots became still more distinct when age-state classes were grouped into three gross categories respectively including all young newcomers (TYN = sMo + sDI + yMO + yDI), all grown newcomers (TAN = nrMO + nrDI + rMO + rDi), and all transplants (TT). It should be noted, however, that annual proportions of age-state classes belonging to the TYN category vs. those included in the TT group were different in plots MG1–MG2 compared to MG3–MG4 (Fig. 5).

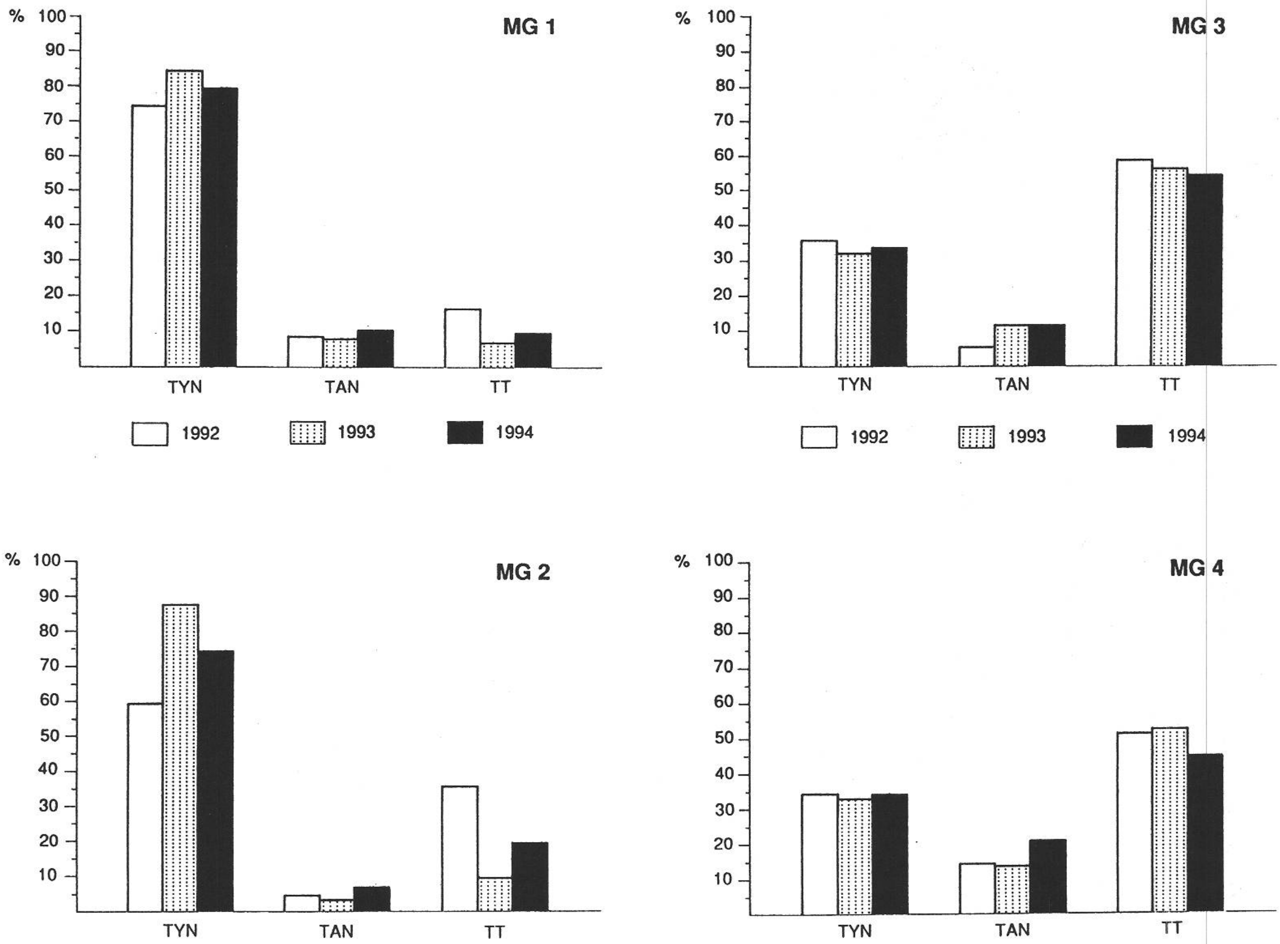


Fig. 5. Annual fluctuations in age-state structure of plot MG1 (above left), MG2 (below left), MG3 (above right) and MG4 (below right).
TYN = sMo + sDi + yMo + yDi; TAN = nrMo + nrDi + rMo + rDi; TT = NR + R + D.

Newcomers of all age-state classes represented the large majority in plots MG1 and MG2 but they hardly ever reached 50 per cent in plots MG3 and MG4. These differences were clearly recognizable both in annual percentages (Fig. 5) and in mean values calculated for three years (Fig. 6).

Discussion and conclusions

The results of this study bring about some interesting insights into assessment of ecological restoration and methodical approaches to this subject. They clearly demonstrate the importance of demographic data to evaluation of post-restoration status of the plots and corroborate thus the opinion of previous authors, also those working in conservation biology research (Pavlik 1994).

Mixed stands in the studied plots were characterized by a full range of age-state classes. The increase in delta diversity (Urbanska, in press) is thus considerable since at the initial phase of restoration only non-reproducing transplants (NR-class) were includ-

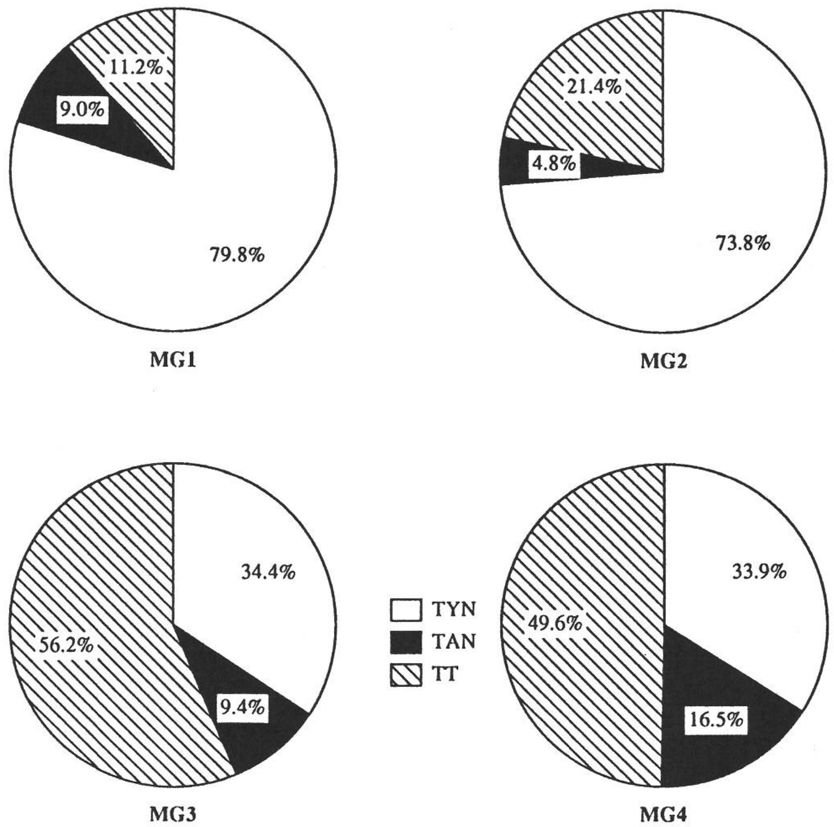


Fig. 6. Age-state structure of the studied plots, mean values of three study years (1992–1994). TYN = sMo + sDi + yMo + yDi; TAN = nrMo + nrDi + rMo + rDi; TT = NR + R + D.

ed. Range of age-state classes and their relative frequencies were routinely used by Russian demographers (Rabotnov 1945, Zhukova and Ermanova 1985) to estimate developmental phases of plant populations. I recently proposed to take this concept one step further and to apply age-state criteria to whole plot communities (Urbanska, in press). Conforming to this proposal, development of communities in the plots dealt with in the present paper may be assessed as early normal phase since all age-state classes are present but rejuvenation is distinct. The results of our study confirm observations of Gasser (1989) concerning early onset of reproduction in transplants; many seedlings and juveniles recorded in the plots are obviously issued from diaspores produced in situ. The same pattern was observed in other trials of our group (e.g. Hasler 1992). The present results clearly demonstrate that inocula of grown plants installed at restoration site represent a potential diaspore source important to the development of self-sustaining communities.

Demographic monitoring of the whole plots described in the present paper is relatively simple as age-state classes do not refer to single plant species but deals instead with general categories like transplants, monocots, and dicots. This simplification notwithstanding, the method is very helpful in mid-term assessment or restoration. It might be worthwhile to try out usefulness of this approach when the situation calls for a rapid assessment and specialist taxonomists are not available. Similar simplified method or recognizable taxonomic unit (RTU) was recently tested for conservation biology purposes and the estimates made by technicians who received only a brief training in taxonomy proved to be sufficiently close to formal taxonomic evaluations (Oliver and Beattie 1993).

Transplantation on a local scale seems to be a promising restoration technique not only in the Swiss Alps but also in other extreme environments (e.g. Forbes 1993, May et al. 1982, Keigley 1988). However, some general guidelines ought to be followed both in regard to the material preparation as well as post-restoration monitoring.

The choice of indigenous plants amenable to cloning and transplantation is obviously very important, but it seems that it is the *species composition* which is decisive. The present study suggests that even considerable losses suffered by one species may be compensated to some extent by a good performance of another one.

Direct transplantation did not work well in our trials (Tschurr 1992). They are also questionable on account of impoverishment of the donor populations (Fahlselt 1988). On the other hand, transplants grown from seed or obtained by cloning from plants non-destructively sampled in donor populations (Urbanska, in press) may be a satisfactory alternative.

One of the most fundamental requirements influencing the final outcome of transplantation are safe-sites. The more extreme the environment, the more carefully safe-site conditions should be provided. Safe-sites should be first determined by a hierarchy of ecosystem-specific risks from which they should protect (Urbanska 1992, Urbanska and Schütz 1986, Urbanska and Hasler 1992).

Safe-sites may be provided in various ways and it is useful to consider primary and secondary effects. As far as primary safe-sites are concerned, soil manipulations are often necessary. In alpine situations, improvement of the soil structure may often be more important than soil fertility increase; plants in extreme environments relay on nutrient uptake and use efficiency rather than a mere nutrient content (Chapin 1980, 1991); on the other hand, physical soil structure seems to be a decisive factor in plant establishment (Flüeler 1992).

Both primary and secondary effects may be expected when biodegradable covers are used to provide safe-sites. Such materials enhance, on the one hand, survival and the subsequent performance of plants used in restoration; on the other hand, they apparently promote a rapid immigration of various plants via diaspore entrapment. Spontaneous immigration of diaspores is exceedingly important to the restoration success since biodiversity increase in vegetation may accelerate development of self-supporting communities without increasing the planting effort (Schuster and Hutnik 1987, McKell 1987, Robinson and Handel 1993). The protective role of biodegradable covers has been documented in our studies above the timberline either by direct microclimatic measurements (Flüeler 1992) or inferred from survival and recruitment rates (Schütz 1988, Tschurr 1992). Extensive immigration of various species into the protected restoration plots was consistently registered in all our trials (Schütz 1988, Tschurr 1992, Hasler 1992, Urbanska, in press, Fattorini, in preparation). The first immigrants arrived in the first summer after the restoration and the most intensive immigration was observed within two-three subsequent years; later on, increase in species number was very slow. This decrease might be influenced by the ongoing development of populations within the plots and the resulting use of most available safe-sites.

Secondary safe-sites may be partially provided be transplants themselves. Seedlings and young plants in the studied plots often occurred within clonal structures of the transplants or in their immidiate vicinity, frequently under the canopy. Studies on these nurse-like relationships are now in progress and data from other areas would be most exciting.

Some previous authors measured transplantation success in alpine tundra by short-term survival and above-ground vegetative growth of the installed plants (e.g. Brown and Johnston 1978, Graber 1980, May et al. 1982). Since successful seedling emergence and recruitment in high-alpine sites may require long time, short-term assessment has only a limited diagnostic value and monitoring should be done over a longer period, preferably in one-two year intervals. The present studies initiated in five- or six-year-old plots follow this schedule because they were preceded by more general observations carried out during the first three years after restoration (Gasser 1989).

Flowering in transplants installed above the timberline was reported only seldom from overseas (Keigley 1988). This deficiency may be due to the short duration of most studies, although results of our group indicate that flowering in transplants may begin already in the first summer after restoration (Urbanska et al. 1987, Tschurr 1992, Hasler 1992, Urbanska, in press). Perhaps the general climatic conditions in the study areas of American authors delay the onset of transplant flowering, but it should be desirable to gather more data on this important aspect.

Some authors are not enthusiastic about transplanting because of high labour costs and questionable suitability for large areas (Cook 1976, Delarze 1994), but long-term success of seeding efforts is uncertain, esp. in extreme ecological situations (Webber and Ives 1978). The time required to establish self-sustaining plant communities by seeding above the timberline is very long so that transplantation may be more cost competitive than some authors believe. I strongly advise therefore that local-scale transplantation be included in rehabilitation or restoration programmes.

At the beginning of this paper I pointed out to some differences between conservation biology and restoration ecology relating to the use of terminology and assessment approaches. It seems that there are also differences as to the suitability of various techniques. For instance, Fahlselt (1988) argued that transplantation should be discouraged as method in conservation biology, particularly since the success rate is low. In 1988, Canadian Botanical Association banned in strong terms the transplanting as a method of conserving rare species. In ecological restoration, on the other hand, transplantation is increasingly gaining importance. Incidentally, transplantation in a program of ecological restoration may also offer an excellent opportunity to reestablish populations of species that became rare in a given area. The amazing population development of *Trisetum spicatum* reintroduced in one of our restoration sites above the timberline (Urbanska, in press) indicates that transplants may be very successful indeed as population founders. Perhaps it would be useful to reconsider the opinion that transplants have no future in conservation biology.

In conclusion, one warning should be issued, however: Even the most successful transplants may be irreversibly destroyed if the impact is too strong. My recent observations on damage caused by senseless use of heavy track machines within our trial area at early spring prove unfortunately that the resilience principle of the restored vegetation does not apply anymore once the damage threshold has been crossed.

Note

The use of trade names in this paper is for reader information and does not imply endorsement of any product by Swiss Federal Institute of Technology.

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Zusammenfassung

Fünf und sechs Jahre alte umweltgerecht renaturierte Flächen auf einer alpinen Skipistenplanierung (rund 2500 m ü. M.) wurden während dreier Jahre überprüft, um den Erfolg der Renaturierung zu erfassen. Das demographische Monitoring bezog sich auf ganze Mischbestände.

Mit der Untersuchung konnte nachgewiesen werden, daß die meisten Verluste von Transplantaten zwischen dem dritten und dem fünften Jahr nach der Renaturierung erfolgten. Die Sterblichkeit der Transplantate in späteren Jahren war allgemein niedrig, aber Skipistenmaschinen können anscheindend auch gut etablierte Pflanzendecken beschädigen bzw. total zerstören. Mittlere Überlebensraten der Transplantate in den untersuchten Flächen, berechnet im Vergleich zum Anfang der Renaturierung, belaufen sich zwischen 1992 und 1994 auf 67,5–76,4% seit 1986 (MG1 und MG2), und 52,6–59,7% seit 1987 (MG3 und MG4).

Demographische Hauptmerkmale der untersuchten Flächen waren (a) stetes Vorkommen aller Alters-Entwicklungsklassen in jeder Fläche und (b) ausgeprägte Verjüngung aller Pflanzengemeinschaften. Diese Eigenschaften zeigen eine fortschreitende Entwicklung der Pflanzendecke auf, die einerseits durch Selbstsaat der Transplantate und andererseits durch intensive Einwanderung der Diasporen sowie die nachfolgende Gründung neuer Populationen beeinflußt wird.

Kleinflächige Transplantationen sowie Nachahmung der Schutzstellen sind als unersetzbare Elemente der umweltgerechten Renaturierung von Skipistenplanierungen zu betrachten. Das demographische Monitoring der Mischbestände erweist sich als sehr hilfreich zur mittelfristigen Erfassung des Renaturierungserfolges.

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