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Microscale revegetation of alpine lichen heath after wild boar digging: fifteen years of observations on permanent plots

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Abstract. The revegetation of alpine lichen heath after one-time wild boar (*Sus scrofa* L.) digging has been studied on permanent plots set up in the alpine belt of the Mount Malaya Khatipara in the Teberda Reserve, the NW Caucasus (2,800 m a.s.l.) for fifteen years. The undisturbed plots of the same size were taken as a control. The cover of vascular plants and lichens has increased but has not reached the control index at the moment. The floristic richness has increased as well and it has exceeded the control one. Only typical for the undisturbed community species were found on disturbed plots but the relationship between species during the revegetation differed considerably. Population density of *Luzula spicata* (L.) DC., *Helictotrichon versicolor* (Vill.) Pillger and *Gentiana pyrenaica* L. has been increasing constantly. It is supposed that these species demonstrate the "explerent" strategy properties (high colonization ability) and they can be recommended for the restoration of alpine lichen heaths.
Key-words: alpine lichen heath, wild boar digging, species richness, revegetation, the Caucasus, disturbance

Introduction

Alpine communities are greatly influenced by different types of natural and antropogenic disturbances. Revegetation successions take a long period of time. That is why the study of recovery of disturbed alpine plant communities is of both theoretical and practical interest (Willard and Marr 1971; Brown, Johnston and Johnson 1978; Urbanska 1986, 1995). But there are only few works based on the direct long-term field observations (Gadzhiev 1979; Frank and Moral del 1986; Tsuyuzaki 1991). Nevertheless it is necessary to carry out a research into the regularities of the natural recovery dynamics in order to work out some practical recommendations. The wild boar digging is rather often in high altitude areas and therefore it may serve as a suitable model of animal and human impact on alpine communities. The aim of this paper is to describe changes in community structure and composition during revegetation.

Material and methods

The study area is located in the alpine belt of the Mount Malaya Khatipara, Teberda Reserve, Karachaevo-Cherkessian Republic, the NW Caucasus, Russia 43°16' N, 41°41' E, altitude 2,800 m. Alpine lichen heath has been served as a object of our investigation. The detailed description of the plant community was published previously (Onipchenko 1985, 1994). There were some patches of total area of about five square meters revealed dug up by wild boars (*Sus scrofa* L.) in autumn 1980. Wild boars dug up the turf horizon of soil extracting apparently large roots of *Carum caucasicum* (Bieb.) Boiss., *Campanula tridentata* Schreb. and *Trifolium polyphyllum* C.A.Mey. The most part of soil surface was deprived of plants that led to the surface frost activity damaging seedlings and young plants. Five permanent plots of 25x25 cm were set up on these patches. Twenty undisturbed plots of the same size were taken as a control. Data have been collected annually during 15 years since 1981 in July and August. The percent cover of vascular plants, lichens and bryophytes was recorded, as well as the percent of bare soil surface. The number of juveniles and the density of vegetative and generative shoots were calculated for each vascular plant species. For the short- and semirosette plants, such as *Campanula tridentata, Eritrichium caucasicum* (Albov.) Grossh., *Anemone speciosa* Adam. ex G.Pritz., the quantity of generative plants instead of generative shoots was counted for the same time period. Data from both disturbed and control plots were summarized. Two methods were used to analyse the obtained data: 1) a comparison of mean shoot density on the disturbed and control plots with the t-test; 2) a calculation of a relative coefficient:

$$K = (N_{t2} \times C_{t1}) / (N_{t1} \times C_{t2})$$

where N_{t1} equals shoot density on the disturbed plots at the beginning of our observations (1981), C_{t1} - the same for the control, N_{t2} and C_{t2} -shoot density after a period of time on the disturbed and control plots, respectively. Because of great year-to-year fluctuations of shoot density in both variants, mean number of shoots out of each two successive years (1982-83 asf) was used for N_{t2} and C_{t2}. K>1 shows that the experimental conditions were probably more favourable that those of the control, and K<1, on the contrary, shows that the experimental conditions were somewhat worse.

Results and discussion

Percent cover

Overall the revegetation of alpine lichen heath has been proceeding slow: the traces of digging are clearly distinguishable even 15 years after the disturbance had happened. The bare soil area has shorted considerably (from 71% to 5% on the average) during the time of our observation, whereas the cover of vascular plants has increased from 2% to 32% getting close to the control one. At the same time the cover of fruticose lichens has reached only 27%. It makes up for approximately the half of the control index. The cover of bryophytes on the disturbed plots has exceeded a few times the control one that has not ever been more than 1% (Fig.1). In all probability it is connected with the sudden nudation of a considerable piece of soil surface after wild boar disturbance. It is supposed that bryophytes species (particularly *Polytrichum juniperinum* Hedw. and *Pohlia nutans* (Hedw.) Lindb.) demonstrate the ability for quick colonization of bare soil areas.

Thus, there is a marked difference between the components of alpine lichen heath in the rate of recovery. The slowest to recover are fruticose lichens. Apparently it is due to the low rate of their growth, especially of *Cetraria islandica* (L.) Ach., *Cladonia mitis* (Sandst.) Hale et W.Culb. and *Thamnolia vermicularis* (Sw.) Ach. ex Shaer. On the other hand, because of frequent strong winds, fruticose lichens cannot develop in the alpine lichen heaths without the "framework" of the community, forming by vascular plants, whereas their floristic composition does not change significantly after removal of lichens (Onipchenko 1985, 1994). It is interesting that the investigation of a New Zealand high-alpine cushion field has yielded similar results: 11 years after mechanical disturbance the lichen cover dominated by *Cetraria islandica, Thamnolia vermicularis* and *Alectoria nigricans* (Ach.) Nyl. has not yet recovered (Roxburgh, Wilson and Mark 1988).

Species richness

We recorded total of 20 vascular plant species on the disturbed plots during the whole period of observation (15 years). The number of species recorded annually has increased from 10 in 1981 to 16 in 1994, as well as the average number per plot (from 5.2 to 10.2, respectively). The t-test shows that difference between the disturbed and control plots is statistically significant at the 1% level in two first years and at the 5% level in the following four. By the year 10 the average vascular plant species number on the disturbed plots was approximately the same as on the control one (Fig.2). Floristic richness per plot increased due to the gradual increasing of the frequency of species registered from the very beginning of our observation (*Luzula spicata* (L.) DC., *Carum caucasicum*) and as well as the arrival of new species (*Eritrichium caucasicum, Veronica gentianoides* Vahl, *Euphrasia ossica* Juz., *Pedicularis comosa* L., *Alchemilla caucasica* Buser). All of the recorded species are typical for alpine lichen heaths. There appeared no species alien for this type of communities. It proves the statement that the species composition of plant communities in the high altitude areas does not change during revegetation

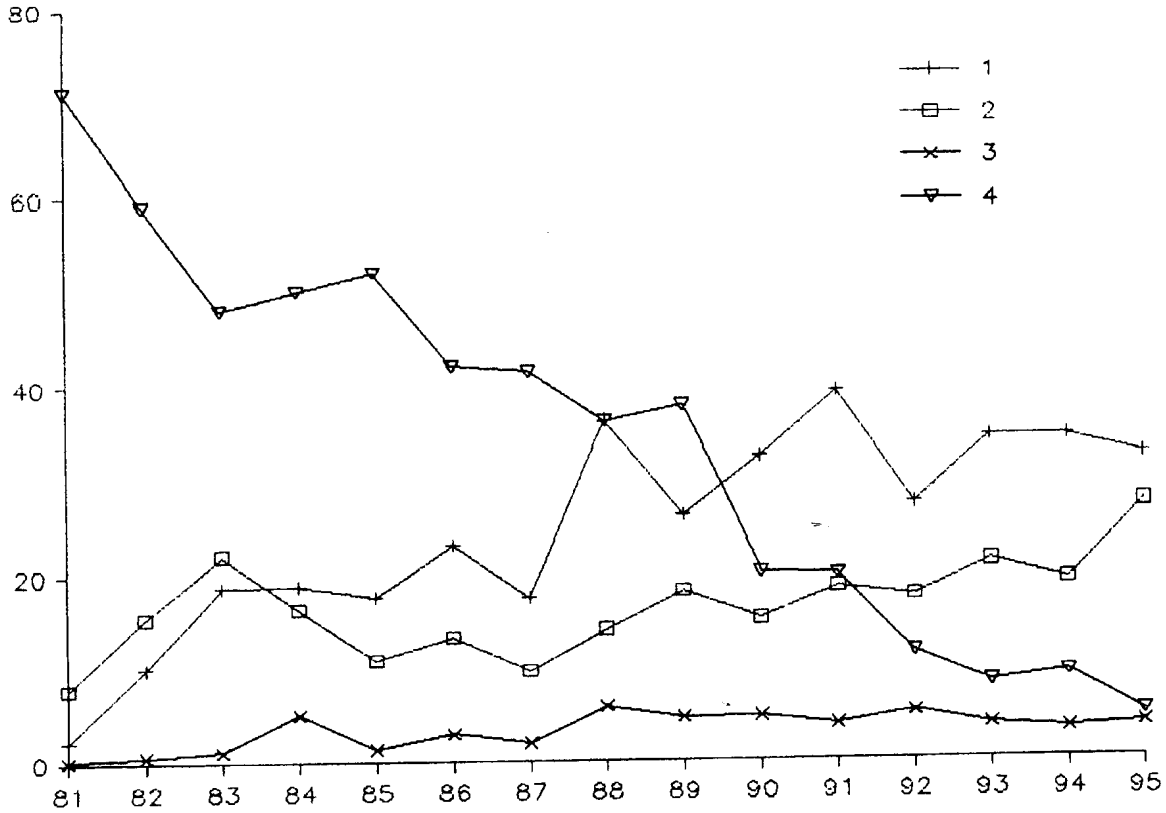

Fig.1. Cover dynamics (%) on the disturbed plots during 15 years after wild boar digging: 1 - vascular plants, 2 - lichens, 3 - bryophytes, 4 - bare soil surface.

Species	P	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	P
Anemone	*	1	3	5	8	3	6	4	7	4	5	6	3	5	6	6	*
speciosa		10	10	15	10	13	14	10	14	13	15	15	14	13	12	17	
Campanula	***	9	30	27	25	42	25	61	65	69	68	73	55	68	106	89	
tridentata		89	81	91	111	124	117	75	120	104	101	129	126	107	115	113	
Carex spp.	*	30	32	57	106	146	151	175	237	215	209	198	203	235	215	167	*
		79	68	103	128	121	115	116	102	76	122	129	175	142	115	82	
Carum		2	5	4	10	14	16	19	51	47	45	51	44	41	51	56	
caucasicum		14	13	18	30	33	24	15	25	24	24	35	33	26	34	47	
Eritrichium	*	-	1	2	1	1	1	2	5	10	11	11	8	8	11	10	**
caucasicum		7	8	10	13	18	14	12	18	19	19	19	23	20	21	27	
Festuca ovina	***	94	171	392	275	319	350	277	481	705	910	791	626	704	825	627	***
		364	254	244	386	272	244	363	387	183	348	341	413	454	406	286	
Gentiana		5	3	5	5	-	1	2	10	10	13	30	51	60	127	137	
pyrenaica		19	29	31	46	44	39	53	65	85	56	75	95	79	100	86	
Helictotrichon	**	1	-	-	-	-	6	10	11	15	31	32	59	59	82	60	
versicolor		44	34	48	61	44	40	43	54	45	45	62	56	53	50	37	
Luzula spicata		4	8	17	29	34	35	35	33	39	44	40	42	40	60	38	***
		2	1	2	4	1	2	2	3	1	3	2	3	1	2	2	
Trifolium		10	19	24	30	27	25	20	23	20	23	23	23	26	27	24	
polyphyllum		40	35	42	41	36	36	32	35	30	33	35	28	33	36	36	

Table 1. Dynamics of shoot number for most abundant species of alpine lichen heaths on disturbed (upper line) and control (lower line) plots during 15 years after wild boar digging (the sum density per 5 plots of 25x25 cm). The significance level of differences according to the t-test is represented for the first and the last year of observations only: * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

successions (McMahon 1982). Severe environmental conditions prevent diaspores of other species from the invasion into disturbed plots.

Shoot density

In the first year of our observation the shoot density of the most species on the disturbed plots was significantly lower than that of the control according to the t-test (Table 1). In the later years the opposite ratio was observed for some graminoids - *Festuca ovina* L., *Luzula spicata*, *Carex* spp. (*C. umbrosa* Host., *C. sempervirens* Vill.) due to the intensive vegetative growth of the plants remaining after the disturbance. The number of generative shoots of these species (especially *Festuca ovina* and *Luzula spicata*) on the disturbed plots is considerably greater than on the control ones (Table 2). It is suggested that these species demonstrate the "explerent" strategy properties sensu Ramenskii (Ramenskii

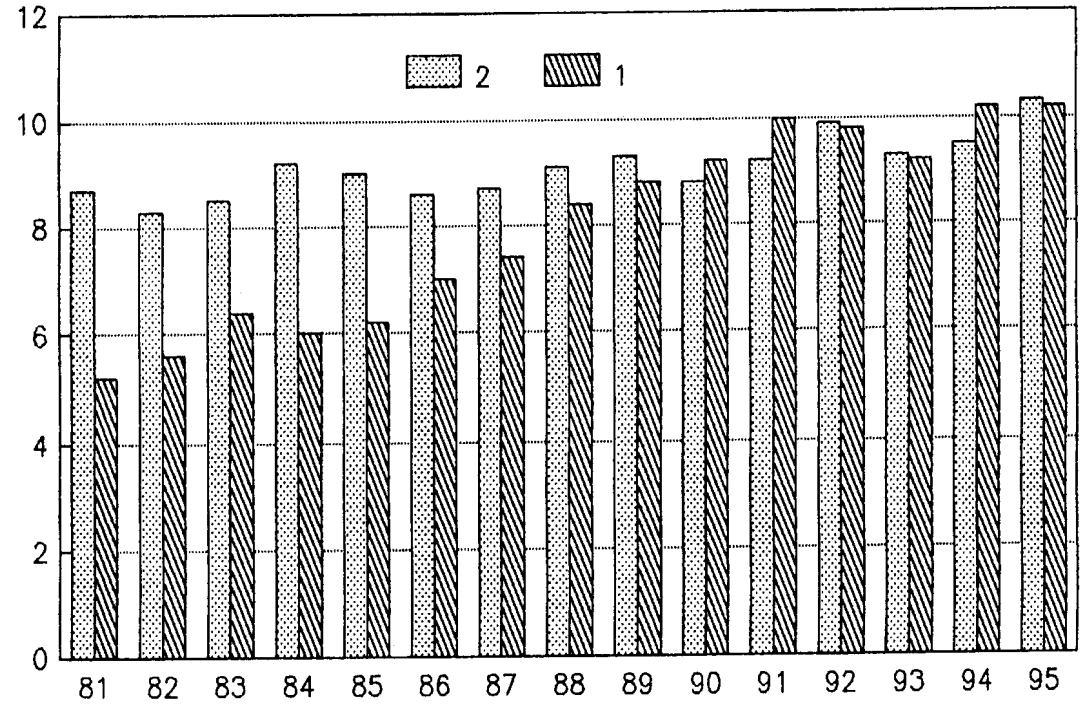

Fig.2. Species richness (the average number of vascular plant species per 25x25 cm plot) for disturbed (1) and control (2) plots during 15 years after wild boar digging.

Year		1981		1988		1995		average ± s.e.		
Area		d	c	d	c	d	c	d	c	P
Campanula	j	-	0.8	44.6	3.5	38.2	23.3	27.2±4.6	12.9±2.5	*
tridentata	v	100	66.6	43.1	68.5	49.4	64.9	58.0±5.2	59.9±2.5	
	g	-	32.6	12.3	28.0	12.4	11.8	14.8±2.8	27.3±2.0	***
Carum	j	-	12.9	86.3	26.0	48.2	63.8	64.7±6.2	35.8±5.3	**
caucasicum	v	100	74.2	9.8	38.0	44.7	20.8	32.7±6.3	40.1±5.4	
	g	-	12.9	3.9	36.0	7.1	15.4	2.7±0.7	24.1±2.0	***
Gentiana	v	80.0	94.7	100	95.4	86.1	98.2	82.0±6.7	93.1±1.0	
pyrenaica	g	20.0	5.3	-	4.6	13.9	1.8	8.0±2.5	6.5±0.8	
Festuca	v	100	99.4	96.7	99.2	97.6	99.0	93.7±1.4	98.5±0.3	**
ovina	g	-	0.6	3.3	0.8	2.4	1.0	6.3±1.4	1.5±0.3	**
Luzula	j	50.0	-	-	-	-	-	3.3±3.2	0.8±0.8	
spicata	v	50.0	87.5	72.7	100	89.5	100	78.2±3.5	95.1±2.2	***
	g	-	12.5	27.3	-	10.5	-	18.5±3.1	4.1±1.9	***

Table 2. Developmental stage composition (%) of some abundant species on disturbed (d) and control (c) plots. j - juveniles; v - vegetative shoots; g - generative shoots.

Species	Years 82-83	84-85	86-87	88-89	90-91	92-93	94-95
Campanula tridentata	3.28	2.83	4.57	5.94	6.06	5.23	8.49
Carex spp.	1.32	2.63	3.74	6.47	4.12	3.64	5.23
Carum caucasicum	1.93	2.57	6.26	13.57	11.03	9.72	8.97
Festuca ovina	4.37	3.49	4.08	8.05	9.55	5.94	8.11
Gentiana pyrenaica	0.51	0.21	0.13	0.51	1.25	2.43	5.42
Helictotrichon versicolor	-	-	8.59	11.48	25.61	47.20	71.00
Luzula spicata	5.00	6.63	8.75	10.29	9.88	10.93	12.25
Trifolium polyphyllum	2.22	2.91	2.70	2.61	2.64	3.13	2.82

Table 3. Dynamics of the relative coefficient (K) for the eight most abundant species.

1938), namely quick clonal growth and colonization ability. There are some observations (Shiffers 1953; Tsareva 1978; Brown and Johnston 1979) that *Luzula spicata* is one of the first plants to occupy the disturbed sites in high altitude areas. It is therefore recommended for the restoration of alpine communities.

Helictotrichon versicolor (Vill.) Pillger and *Gentiana pyrenaica* L. have been registered regularly on the disturbed plots since 1986. From that time population density of these species has been increasing constantly, what is confirmed by continuous increasing of a relative coefficient K (Table 3). Though K is more than 1 for all observed species, the greater index is belonging to *Helictotrichon versicolor*. *Helictotrichon versicolor* is a loose-bunch grass. It even has been studied in Switzerland as a potential object for artificial revegetation of disturbed sites (Tschurr 1992). *Gentiana pyrenaica* having its draft-trailing shoots is also capable of successful colonization of vacant space. The not high index of K for this species can be explained by considerable increasing of shoot density in the control.

On the contrary, generative reproduction is the main factor of restoration of taprooted polycarpics, such as *Carum caucasicum* and *Campanula tridentata*. Their seedlings has appeared on the dug plots in the following fashion: 1) from the soil seed bank (Semenova and Onipchenko 1994); 2) from the adult individuals remained on site after disturbance; 3) from the nearest surroundings. That is why part of juveniles in population structure of these species on the disturbed plots is significantly greater than on the control ones. On the other hand, the portion of generative plants is considerably less than in the control.

The shoot density of *Anemone speciosa* has been recovering very slow. Apparently, this fact can be

explained by its small seed yield capaciy and the lack of vegetative reproduction (the same holds true for *Eritrichium caucasicum*).

The results of our research allow to conclude that the species composition does not change considerably during local revegetation in the alpine zone. The most abundant species of alpine lichen heath remained dominants on the disturbed plots. Disturbance changes only the relative role of some groups of species. By virtue of our investigation we propose characteristic features to distinguish stages of revegetation of alpine lichen heath from the undisturbed communities (at least during several ten-year periods): 1) presence of some patches of bare soil surface; 2) low coverage of fruticose lichens; 3) the greater abundance of graminoids; 4) low abundance of *Anemone speciosa*.

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