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Alpine Steppe Vegetation Patterns in the Koyondu Valley, Kyrgyz Republic

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Abstract

As a part of an ecological research project on wild animals, alpine steppe vegetation in the Koyondu Valley, the Sarychat-Ertash State Reserve, in the northern Tian Shan Mountains of the Kyrgyz Republic was surveyed. Horses and sheep were kept as livestock, while wildlife such as Marco Polo sheep (argali) and wolves also inhabited the region. Information regarding wildlife, weather conditions and the livelihood of human inhabitants within the region was scarce and difficult to obtain. In May 2011, 21 relevé plots from 5 types of vegetational physiognomy were established at elevations ranging from ca. 3,400 to 3,600 m. In each plot, coverage, sociability and height of each plant species were measured. As a result, vegetation physiognomy of type IV plots (grassland with accumulated detritus) proved to have by far the greatest coverage and v-values of all physiognomy types. Seven varieties of plant community (A1 to A4 and B1 to B3) were recognized based on differing combinations of 4 differential plant species. Varieties of plant community did not exactly correspond to types of vegetation physiognomy, and type IV plots displayed the most variability. Distribution patterns of each community in relation to elevation and slope direction appeared similar on both the left (facing southwest) and right (facing northeast) banks of the valley, but exceptions were observed more frequently on the left bank than the right. When v-value was plotted against the total number of plant species present, the majority of plots fell within a successive transition. Type IV plots, however, were out of this transition and possessed exceptionally abundant vegetation.

Key words：The Kyrgyz Republic, Tian Shan Mountains, alpine steppe, plant community, detritus, elevation, slope direction

Ⅰ. Introduction

Alpine plants develop under severe environmental conditions, including exposure to low temperatures; drying; freezing and thawing of the soil; movement of the soil surface; strong winds; and exposure to ultraviolet rays (Masuzawa, 1997; Kikuchi, 2003). Recovery of alpine vegetation in decline is made difficult by the low survival rate of seedlings outside of safe sites (Erschbamer et al., 2001) and the erosion or deterioration of bare soil (Tamura and Cheng, 2009).

It has also been suspected that alpine vegetation in Japan is damaged by wildlife, such as sika deer, that invade the alpine zone (Izumiyama and Mochizuki, 2008). Alpine zones that lack the regular presence of herbivores, such as those found in Japan, are a minority, while most alpine zones, such as those in Europe, Asia and South America, often serve as grazing sites for livestock (Takatsuki, 2003). Through understanding the

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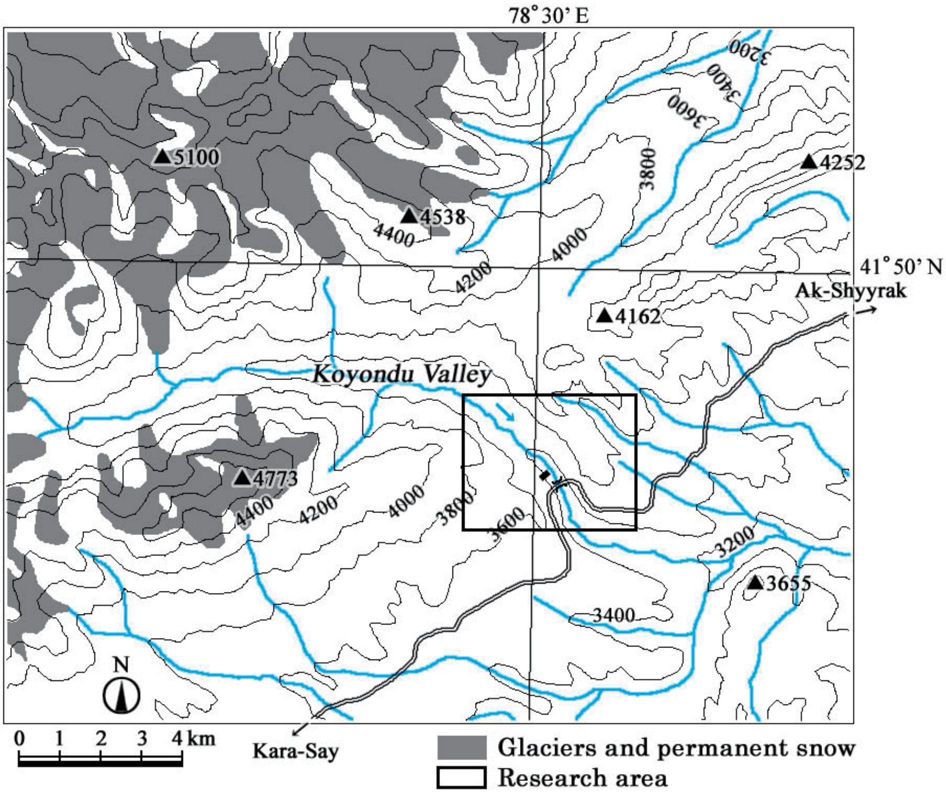

Fig. 1. Geomorphology of Koyondu Valley and location of the study area

development and distribution of alpine vegetation exposed to continuous grazing, it was believed that information that could aid in the conservation of similar vegetation in Japan could be obtained.

The present study focused on the Koyondu Valley located within the Sarychat-Ertash State Reserve in the Kyrgyz Republic (Fig. 1), an alpine zone inhabited by both livestock and wildlife. The study site was located in an area formed by glacial erosion at the northern foot of the Tian Shan Mountains at an elevation of over 3,400 m. Horses and sheep were kept as livestock in the area, while herbivores such as Marco Polo sheep (argali), ibex and deer, as well as carnivores such as wolves, snow leopards and brown bears, also inhabited the region. Information regarding wildlife, weather conditions and the livelihood of human inhabitants within the region was scarce and difficult to obtain. Only a few preliminary surveys are available on steppe vegetation within the Koyondu Valley (Arase et al., 2011) and flora around the forest limit within the neighboring Ertash Valley (Arase et al., 2012) as well as a study on glacier retreat by Solomina et al. (2004).

Many tourists visit the Kyrgyz Republic due to the scenic nature of its mountainous terrain and the country faces a number of problems that have arisen due to the conflicting interests of tourism and environmental conservation. Trophy hunting of wildlife by wealthy foreigners is currently a large source of income for the country, and locals gather excessive amounts of shrubs for use as fuel (Watanabe et al., 2008).

In the present study, as a part of an ecological research project that examined wild animals in the Sarychat-Ertash State Reserve, alpine steppe vegetation over the forest line (at an elevation between ca. 3,400 and 3,600 m) was surveyed at a study site within the Koyondu Valley. Different types of vegetational physiognomy and plant communities were identified along with their distributions, and patterns of vegetation in relation to variations in habitat were discussed.

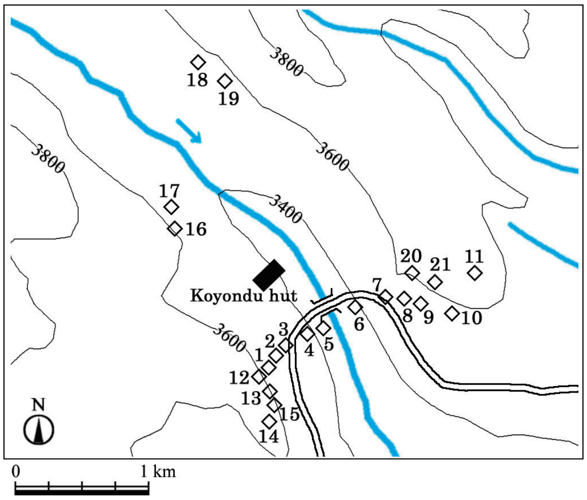

Fig. 2. Locations of relevé plots

Ⅱ. Methods

In May 2011, 21 relevé plots (2m × 2m) were established on both the left and the right banks of the valley (Fig. 2). Location of plots was determined based on 5 vegetation types distinguished by vegetation physiognomy that were observed in the survey area (Figs. 3 to 7):

1) type I: grassland located on the flat valley bottom of the glacial trough (7 plots);

2) type II: sparse grassland located on the lower-slopes of lateral moraines (2 plots);

3) type III: stripped grassland located on the mid-slope of lateral moraines (5 plots);

4) type IV: grassland with accumulated detritus located on the mid- and upper-slopes of the lateral moraines (5 plots). In our rough observation, the detritus size in the survey area was mostly as large as 15 to 30 cm in diameter (over 100 cm at the largest and 2 cm at the smallest);

5) type V: grassland located on the ridge of lateral moraines (2 plots).

In addition, there existed a small area of bare ground located on the lower-slope of the lateral moraines within the study area (Fig. 8) that lacked vegetation and showed signs of salt accumulation.

In each plot, coverage, sociability and height of each plant species present were measured. Spe-

Fig. 3. Type I vegetation physiognomy
Photographed in relevé No. 4, 1st of May, 2011.

Fig. 4. Type II vegetation physiognomy
Photographed in relevé No. 2, 1st of May, 2011.

Fig. 5. Type III vegetation physiognomy
Photographed in relevé No. 12, 3rd of May, 2011.

Fig. 6. Type IV vegetation physiognomy
Photographed in relevé No. 16, 3rd of May, 2011.

Fig. 7. Type V vegetation physiognomy
Photographed in relevé No. 14, 3rd of May, 2011.

Fig. 8. Bare ground with salt accumulation located in the study area
Photographed 3rd of May, 2011.

cies identification was carried out in accordance with methodology outlined in previous studies conducted by Konta and Shimizu (1996) and Osada (1993). Plant coverage and sociability were ranked using classes from the Brawn-Branquet scale. Coverage classes were determined as follows:

+: vegetation was sparse and covered an area less than 1% of the total plot area;
1: vegetation covered between 1 and 10% of total plot area;
2: vegetation covered between 10 and 25% of total plot area;
3: vegetation covered between 25 and 50% of total plot area;
4: vegetation covered between 50 and 75% of total plot area;
5: vegetation covered more than 75% of total plot area.

Sociability classes were determined as follows:
1: plants grew individually;
2: plants grew in clusters;
3: plants grew in small patches;
4: plants grew in large patches with gaps;
5: plant growth covered the entire study plot.

Plant communities were classified using the relevé method through rearrangement of the order of species (lateral lines) and relevé plots (vertical columns) based on similarities to a species-composition table. V-values were calculated as an estimate of above ground biomass for each plot (Kawada et al., 2005) according to the following formula:

$$\text{v-value (cm}^3) = \Sigma\{\text{ coverage (\%)} \cdot \text{plant height (cm)} \cdot \text{plot area (cm}^2)\ \}.$$

This value represented an approximation of the total volume of vegetation within a given plot and has been reported to have a significant correlation with actual biomass (Kawada et al., 2005; Arase, 2012). Values for coverage percentage used in the calculation of v-value were obtained by converting each coverage class into a single percentage (e.g., class ‘5’, which comprised coverages between 75 and 100%, was converted into a value of 87.5%). Classification of habitat environment was based on characteristics such as land surface composition, grazing pressure, slope direction and elevation, and was determined through visual observation as well as a portable GPS.

Data analysis was conducted using spreadsheet software (Microsoft Excel 2003). Analysis of variance (ANOVA) and Tukey’s honest significant difference method (HSD) were used in order to identify significant differences in plant growth among vegetation types. Data regarding vegetational coverage (%) were transformed using arcsine-root function for normalization. Previously published statistic tables (Yamauchi, 1977) were referred to when determining significance in both HSD and non-parametric correlation.

Ⅲ. Results

Vegetational coverage and v-values of 5 vegetation types are presented in Fig. 9. Coverage within type I and IV plots (31.0 and 37.0 % on average, respectively) was significantly greater than that in other plot types (from 7.0 to 15.0%) (Tukey’s HSD method, $p < 0.05$). Average v-value of type IV plots (15.9×10^5 $cm^3 \cdot m^{-2}$) was significantly greater than in other plot types (from 0.6 to 5.3) (Tukey’s HSD method, $p < 0.01$). Type IV plots proved to have the greatest vegetational coverage and v-values of all vegetation types. Type I plots had greater vegetational coverage than type III plots, but both types of plot possessed similar v-values.

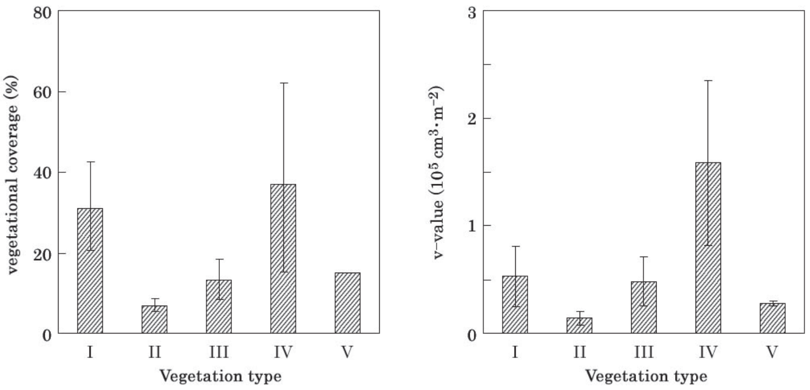

Fig. 9. Vegetational coverage and v-values for 5 different vegetation types

Table 1. Species composition within each relevé plot
Seven varieties of plant community (A1 to A4 and B1 to B3) were recognized based on differing combinations of 4 differential plant species.

Layer	Species name	Relevé No.																				
		1	2	4	9	7	8	3	5	6	21	12	17	20	10	13	18	16	19	11	14	15
	Vegetation physiognomy	II	II	I	I	I	I	I	I	I	III	III	III	IV	I	IV	IV	IV	III	V	V	IV
	Vegetational cover (%)	6	8	40	20	20	25	30	50	35	15	10	10	18	22	60	50	55	10	15	15	50
	Number of species	3	6	9	7	6	4	9	13	6	6	4	5	6	5	15	7	13	7	5	6	7
	Plant community	A1		A2			A3					A4					B1	B2		B3		
shrub layer	*Caragana jubata*																	2·3				
herbaceous layer	*Poa* sp.			1·1	+		+	1·1	1·2	1·1	+	1·1	+	+		2·2	1·2	1·2	+		+	
	Leymus secalinus			1·2	1·2	+			2·2	1·2	+								1·1			
	Geum sp.		+					+	+					+		+	+	+			+	
	Gentiana sp.1							+	+							+		+		+		
	Primula sp.			+					+													1·1
	Artemisia sp.	1·2	1·2	1·1	1·1	2·2	2·2	1·2	1·1	1·2	1·2	1·2	2·2	1·1	1·2	1·2						
	Lepidium sp.		+		+	+		+	+						+							
	Trisetum sibilicum	+		3·3	2·2	1·2		+					1·1	1·2	1·2	2·2	1·2	1·2	1·2			
	Leontospodium sp.			1·1												+		+				
	Stipa alpina		+	+	+		1·2	3·3	2·2	2·3	1·1						3·3					
	Oxytropis paniciflora			+				+		+							+					
	Cladoniaceae sp. (lichen)						+	1·1									+			+		
	Trisetum spicatum	+	+										1·1	1·2	1·2	1·1		2·3	1·1	1·2	1·1	1·1
	Elymus sp.				+							1·2		+	1·1	1·1		2·2	+	1·2		
	Sausurea sp.												+			1·1		+		1·2	1·2	
	Draba sp.		+	+								+				+		+			+	+
	Taraxacum sp.					+										+						
	Sagina sp.					+													+			
	Melandryum sp.								+							1·1						
	Gentiana sp.2								+							+						
	Ranunculus sp.								+													
	Carex sp.2								+													
	Carex sp.3								+													
	Erigeron sp.									+												
	Deschampsia flexuosa										2·2										1·2	
	Arabis sp.										+								+			
	Gagea sp.															+						
	Carex sp.1															+						
	Astragalus sp.																+					
	Carex sp.4																	1·2				
	Adenophora sp.																	+				
	Ephedra sp.																	+				
	Festuca sp.																					3·3
	Tilingia sp.																					+
	Boraginaceae sp.																					+
	Orchidaceae sp.																					+

Species compositions within each relevé plot are shown in Table 1. Seven types of plant community were recognized (A1 to A4 and B1 to B3), based on combinations of 4 differential plant species. These differential species were described as follows:

1) group 1: *Artemisia* sp. accompanied by *Lepidium* sp.; the principal group that determined the 2 main groupings of the plant communities (A and B);

2) group 2: *Trisetum sibilicum* accompanied by *Leontopodium* sp.;

3) group 3: *Stipa alpina* accompanied by *Oxytropis paniciflora* and Cladoniaceae sp.;

4) group 4: *Trisetum spicatum* accompanied by *Elymus* sp., *Sausurea* sp. and *Draba* sp.

Characteristics of each of 7 plant communities were described as follows:

1) A1: only group 1 species were present. This group corresponded to type II plots;

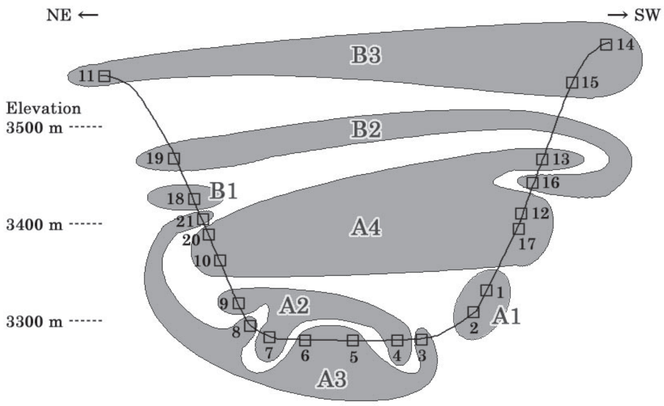

Fig. 10. Distribution of plantcommunities in relation to elevation

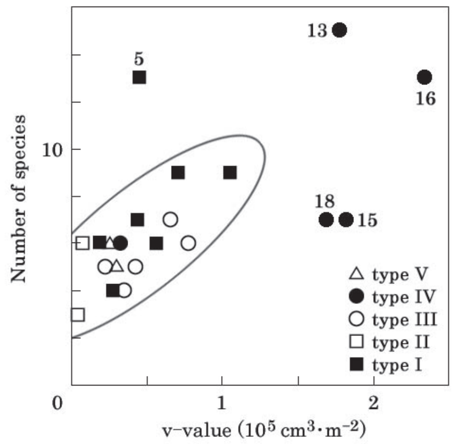

Fig. 11. Relationship between v-value (x-axis) and number of species (y-axis) of each relevé plot

2) A2: species from groups 1 and 2 were present;
3) A3: species from groups 1 and 3 were present. The majority of type I plots were comprised of species from groups A2 and A3;
4) A4: species from groups 1, 2 and 4 were present. Type III and type IV plots were comprised of species from this group;
5) B1: species from groups 2 and 3 were present. Only one plot (No.18 relevé, type IV) contained this combination of plant species;
6) B2: species from groups 2 and 4 were present;
7) B3: only species from group 4 were present. Type IV and type V plots comprised B2 and B3 assemblages.

Distributions of each community in relation to elevation and slope direction are shown in Fig. 10. Communities A1 through A4 tended to be distributed along the bottom of the glacial trough and on the lower slopes of lateral moraines, while communities B1 through B3 were distributed along mid- and upper-slopes. Community distribution patterns appeared similar on both the left (facing southwest) and right banks (facing northeast) of the valley. A1 and B1 communities, however, were only found one-sidedly on the right bank and left bank, respectively. Observations also showed that *Caragana jubata* bushes were present only in relevé plot No. 16 (type IV and B2), while marshland was observed only in relevé plot No. 15 (type IV and B3), both of which were located on the right bank of the valley. Kendall's rank correlation coefficient (r_K) was calculated based on elevation and plant community composition for both the left and right banks of the valley. Values of r_K were 0.818 (p <0.001) and 0.667 (p <0.01) for the right and left banks, respectively.

In order to determine relationships among plant communities, each relevé plot was represented on a graph with v-values along the x-axis and number of species along the y-axis (Fig. 11). Figure 11 indicated that the majority of plots seemed to fall within a successive transition with the exception of 5 discontinuous plots which possessed greater v-values or number of species. In these plots, the ratio of type IV plant species (No.13, 15, 16 and 18) was significantly greater than it was in other plots (χ^2-test, p <0.01). The ratio of type IV plant species within plots on the right bank of the valley (Nos. 5, 13, 15 and 16) also seemed greater, but no significant difference was determined (χ^2-test, p =0.157; ns).

Ⅳ. Discussion

It was notable that type IV plots possessed significantly greater v-values than other plot types (Fig. 9). Type I plots displayed vegetational coverage similar to that of type IV plots, meaning that average plant height was greater in type IV plots. Type IV plots contained accumulated detritus, which might have impeded the ability of herbivores to graze. Furthermore, detritus would have increased soil moisture content by allowing for the retention of dew (Kaseke et al., 2012), which could have further stimulated plant growth. Results of the present study were consistent with previous reports of both rocks in deserts and accumulated detritus in alpine areas giving refuge to plants (Masuzawa, 1997; Danin, 1999; Kikuchi, 2003; Arase et al., 2012).

Seven plant communities (A1 to A4 and B1 to B3), which were distinguished based on species composition and did not exactly correspond with types of vegetation physiognomy, were identified in the present study (Table 1). Type II plots were composed entirely of A1 communities, where only *Artemisia* sp. were dominant. It was suspected that *Artemisia* sp. present in the study area prevented the growth of other species and resulted in the sparse vegetation observed in type II plots. This conclusion was based on a previous study in which an *Artemisia* species closely related to the ones observed in the present study had exhibited strong allelopathic behavior (Li et al., 2011). On the other hand, type IV plots varied greatly, exhibiting A4, B1, B2 and B3 plant communities. The variety of plant communities present in type IV plots indicated that accumulated detritus facilitated dominance in a range of plant species.

Figure 10 shows the influences of site elevation and slope direction on the vertical distribution patterns of plant communities. Plant communities were distributed in a similar order on both the left and right banks of the valley examined in the present study (Fig. 10). Inconsistencies in vertical distributions of plant communities occurred more frequently along the left bank of the valley, which resulted in that side having a smaller Kendall's correlation coefficient (r_K =0.667). These results suggested that two patterns of alpine plant community distribution were present in the study area; site elevation resulted in a macro-scale pattern of community distribution, while slope direction resulted in the development of a distribution pattern on a micro-scale. The effects of elevation (Holten, 1998; Kuhle, 2007, Arase et al., 2012) and slope direction (Masuzawa, 1997; Kikuchi, 2003; Sekulová and Hájek, 2009; Raffl et al., 2006; Arase et al., 2011) on alpine vegetation have been well studied and in the present study elevation seemed to be the primary factor affecting the distribution of plant communities. Variation in slope direction at the study site appeared to affect productivity of detritus by altering insulation and soil humidity, which likely resulted in the irregular distribution of plant communities that was observed.

The majority of study plots seemed to fall within a successive range of plant community types (Fig. 11). This implied that all vegetation within the study area, from the bottom of the glacial trough to the ridges of lateral moraines, was regulated by a common relationship between aboveground biomass and species richness. Site location and replacement of species resulted in the observed differences in physiognomy and plant community composition. Type IV plots were exceptional in that they possessed abundant vegetation. This suggested that accumulated detritus facilitated the survival and growth of various plant species. Therefore, distribution of detritus was believed to indirectly influence the migration of herbivores (Izumiyama and Mochizuki, 2008) thereby limiting grazing area in mountain pastures (Jewel et al., 2005).

V. Conclusions

As a part of an ecological research project on wild animals in the Sarychat-Ertash State Reserve, alpine steppe vegetation in the Koyondu Valley in the northern Tian Shan Mountains of the Kyrgyz Republic was surveyed in the present study.

In May 2011, 21 relevé plots (2 m × 2 m per plot) were established at elevations ranging from ca. 3,400 to 3,600 m in order to encompass 5 types of vegetational physiognomy. In each plot, coverage, sociability and height of each plant species were measured. Plant communities were classified using the relevé method based on a species-composition table. V-values were calculated as estimates of above ground biomass by multiplying coverage and plant height. Results showed that:

1) Vegetation physiognomy of type IV plots proved to have by far the greatest coverage and v-values of all physiognomy types. Type I plots were comparable to type IV plots in coverage, but were similar to type III plots in v-value.

2) Seven varieties of plant community (A1 to A4 and B1 to B3) were recognized based on differing combinations of 4 differential plant species. Varieties of plant community did not exactly correspond to types of vegetation physiognomy. Type IV plots displayed the most variability, being composed of 4 different varieties of plant community, which indicated that accumulated detritus facilitated dominance in a variety of plant species.

3) Distribution patterns of each community in relation to elevation and slope direction appeared similar on both the left and right banks of the valley; however, exceptions to these patterns were observed more frequently on the left bank than the right.

4) When v-value was plotted against the total number of plant species present, the majority of plots seemed to fall within a successive transition. This implied that all vegetation within the study area, from the bottom of the glacial trough to the ridges of lateral moraines, was regulated by a common relationship between aboveground biomass and species richness. Site location and replacement of species resulted in the observed differences in physiognomy and plant community composition. Type IV plots, however, possessed abundant vegetation.

Further investigation into the patterns of plant community distribution observed in the present study as well as the exceptions to those patterns will aid in conservation of vegetation and survey of wildlife within a variety of alpine areas.

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