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Variation of the population structure of Polygonum viviparum L. in relation to certain environmental conditions

Peter Milan Petersen

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Populations of *Polygonum viviparum* L. have been studied at Godhavn in Greenland (69° 14′ N, 53° 31′ W), at 30 sites within an investigation area of approx. six km². At each site, the age structure of the population was described after the individuals had been classified on the basis of the morphology of the rhizome. Other population parameters investigated are the total number of individuals (1 – 2,860 per m²), number of recently established individuals (0 – 1,720 per m²), number of flowering individuals (0 – 850 per m²), number of bulbils produced (0 – 17,870 per m²), and dry weight of standing crop (0.6 – 281 g per m²); the numbers in the brackets give the total range for the 30 sites. The flowering individuals have been characterized by the age class in which flowering first occurs, the mean dry weight of the vegetative parts (0.06 – 0.94 g) and the mean number of bulbils (9± 4 – 114 ± 46). – The environmental parameters studied include height above sea level, slope and direction of slope, soil water content, loss on ignition, bulk density, pH, exchangeable K, 0.2 N H_2SO_4-soluble P, C/N, soil temperature, time of disappearance of the snow, soil movement, and degree of cover of the vegetation. The sites have been assigned to six groups which are defined with emphasis on those factors which are assumed to be limiting: 1. Sites with soil movement, 2. Sites where the snow is late in disappearing, 3. Sites with waterlogged soil, 4. Well-drained sites on level or slightly sloping ground, 5. Steep slopes, exposed to the sun, and 6. Sites where competition for light is an important factor. Within each of the groups, the sites show a number of common features, especially as regards relative values referring to the population structure, and various features characterizing the plants. It is suggested that the large variation in the population parameters mentioned above occurs mainly because individuals of *Polygonum viviparum* of a different age are in a different way and to a different degree influenced by the environmental conditions. At the same time, the bulbil gain from and loss to the surroundings is stressed as important for the size of a population.

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Introduction

Polygonum viviparum L. is a perennial, pollacanthic rhizomatous geophyte with a wide distribution in the Arctic and the northern part of the temperate zone, as well as in alpine areas of other parts of the northern hemisphere. Propagation is exclusively vegetative by means of bulbils which are formed on the lower part of the flower bearing spike.

Polygonum viviparum has a broad ecological amplitude and occurs in a wide variety of plant communities in the Arctic. It is an important constituent of many arctic ecosystems. In East Greenland, for example, the bulbils are a very important source of food for the ptarmigan (Gelting 1937) and the snow bunting, and the rhizomes are eaten by the ptarmigan, the arctic hare and the lemming. Moreover, *Polygonum viviparum* is the host plant for a number of parasitic fungi.

The aim of the present investigation is to describe the variation of the population structure of *Polygonum viviparum* at a number of sites (coenopopulations, as defined by Rabotnov (1978)) within a geographically limited area and to relate this variation to the variation in certain environmental conditions. Concomitantly, the morphological variation of the species in relation to the environmental conditions is investigated (Kirsten Engell, in prep.).

The investigation area

The investigation area is situated on the south coast of Disko Island in Greenland, at Godhavn, 69° 14′ N, 53° 31′ W. The climate is low arctic and sub-oceanic; in Godhavn, at sea level, the mean temperature in July is 6.7° C and the annual precipitation 468 mm (9 years, 1962–1970).

The investigation area, approximately six km² reaches from sea level to 700 m a.s.l.. The geological substrate is basalt and gneiss, and there is a large variation as regards soil and vegetation. Due to the topography, sites on level ground dominate the area together with sites sloping to the east, south or west.

Methods

Selection and description of the sites.

Between July 21 and August 5 1977 a total of 35 sites was investigated, 30 with and 5 without *Polygonum viviparum*. The sites were selected in such a way that all important vegetation types were represented. The area of the sites ranged from about one to approximately ten m². At each site, a list was made of the dominating species of vascular plants and mosses. A rough estimate was made of the percentage of ground covered with mosses, lichens, vascular plants, litter, stones and naked soil respectively. The thickness of any moss or litter layer present was noted together with the degree of cover of the vegetation at a height of 10 cm and more. Finally, the occurrence of a few, easily recognizable fungi parasitic on *Polygonum viviparum* was noted.

At each site two separate samples were taken to a depth of 10 cm with a soil corer, 4.4 cm in diameter. These were used for the determination of soil water content, bulk density, and other edaphic parameters. At a very wet site, a water sample was taken. Finally, the height above sea level, the inclination and the direction of slope were determined.

Treatment and analysis of soil samples

The samples for determination of soil water content and bulk density were weighed, dried in paper bags at 105° C, and then weighed again. A subsample was ignited at 400° C for six hours and the loss on ignition determined. The soil water content was calculated both on a volume basis (per cent by volume) and on the basis of the content of organic matter (g water/100 g loss on ignition). The reason for using the latter basis is that the field capacity of the soils in the investigation area is largely determined by their content of organic matter. – Generally, a single determination of soil water content is of no value when characterizing the moisture conditions of a site. However, in the present case, the sampling was undertaken after a long period of drought, so the measurements obtained can be regarded as minimum values and thus comparable (the precipitation in July 1977 amounted to only 10 mm).

Samples for the measurement of other edaphic parameters were dried in paper bags at 60° C. Subsequently they were weighed, comminuted in a morter and passed through a 2 mm sieve, in order to remove stones, gravel, and plant roots. pH, exchangeable K, 0.2 N H_2SO_4-soluble P, total N and total C were determined on the fraction passing the sieve.

For the pH-measurement, 20.0 g of soil were shaken thoroughly with 50 ml of deionized water and left overnight. The next day after filtration the pH of the extract was measured by means of a combined glass-calomel electrode, on a Radiometer pH-meter PHM 62.

Exchangeable K was extracted by means of a 1 M solution of ammoniumacetate, pH 7.0 ± 0.2 . 20.0 g of soil were shaken thoroughly in 80 ml of ammoniumacetate-solution. The following day, the sample was again shaken and the extract decanted through a filter into another flask. The soil was washed twice with 40 ml and twice with 20 ml ammoniumacetate-solution and the extract collected in the flask, which finally was filled to a total volume of 200 ml with ammoniumacetate-solution. The concentration of K in the extract was measured on a Beckman KLINA flame photometer. The content of exchangeable K in the soil was calculated as ppm in the dry, sieved soil.

P was extracted by means of 0.2 N H_2SO_4. To 1.00 g of soil was added 200 ml of H_2SO_4 followed by thorough shaking. Next day the extract was shaken and filtrated. The concentration of P in the extract was determined by means of a Bausch & Lomb spectrophotometer, Spectronic 20, after addition of ammonium molybdate according to Jacksons Method I (Jackson 1958). The content of P in the soil was calculated as ppm in the dry, sieved soil.

Total N was determined on a subsample of 3.00 – 9.00 g after destruction in concentrated H_2SO_4, NH_4^+ in the solution was determined by a specific ammonia electrode, Orion 95 – 10. The content of N in the soil was calculated as ppm in the dry, sieved soil.

Total C was determined on a subsample of 0.05 g, on a Leco Induction Furnace GC 90, in which the CO_2 developed by combustion is collected and weighed. Total C was calculated from two independently measured values, as ppm in the dry, sieved soil. The difference between the two values did not exceed 10% of the mean value. From total N and total C, the C/N-ratio was calculated.

At the wettest sites the possible occurrence of S^{--} was tested for by means of a blank silver wire placed in the soil and examined after four days.

Other environmental parameters

The time of disappearance of the snow, and soil temperature during the period of growth are among the environmental conditions which may be of importance to the plants in the investigation area. Neither of these factors was measured in connection with the investigation in 1977. However, a number of observations and measurements are available from the author's stay in Godhavn 1970–72 (Petersen 1977). Thus the time of disappearance of the snow in three years is known for some of the sites, as well as maximum and minimum temperatures at the soil-litter interface and at a depth of 10 cm in the soil, measured at intervals of ten days throughout the growing period.

Population structure of *Polygonum viviparum*

At each site, a number of circular sample plots each of 0.1 m^2 were marked out along a line or in a square grid, at intervals of 0.5 m. In each sample plot, all individuals of *Polygonum viviparum* were dug up. The number of sample plots varied from site to site. When either the number of individuals exceeded 100, or the number of sample plots laid out amounted to 25, no more sample plots were laid out. These limits were set in order to keep the practical work within reasonable bounds. The number of individuals in each of the sample plots was noted (cfr. Tables 3 and 4).

On the basis of the individuals collected, the population structure at each site was described. The individuals were grouped into six classes. (Fig. 1):

Class I: Individuals still attached to the bulbil and with one or a few leaves.

Class II: Individuals still attached to the bulbil and with a short but marked rhizome (generally of approximately the same size as the bulbil).

Class III: Individuals still attached to the bulbil or not so, with a short rhizome of uniform thickness and with a distinct knee.

Class IV: Individuals still attached to the bulbil, or not so, with a rhizome which is alive throughout its length, curved, and distinctly increasing in thickness from its distal to its proximal end.

Class V: Individuals with a rhizome, which distinctly increases in thickness from its distal to its proximal end, which is S-shaped and which may or may not be alive throughout its length.

Class VI: Individuals with a rhizome which is S-shaped or bent several times, which is distally dead, and where the living part is of uniform thickness. Often with large amounts of attached dead material (remnants of scapes and leafstalks).

Within each class, the number of flowering and non-flowering individuals was counted. Furthermore, the number of spikes on each flowering individual was counted, as well as the number of bulbils on the spikes.

The classification scheme used is a somewhat modified version of that of Hald (1974). Each class presumably corresponds to an age class (a cohort), except Class VI, which consists of individuals that are six or more years old. However, no direct observations have been made which can confirm this assumption.

The classification scheme based on the morphology of the rhizome could not be used at sites with a thick moss carpet, where the rhizomes were often more or less straight and elongated. The classification of the plants from this type of site became subject to additional uncertainty because the rhizomes were often cut during the excavation. At some of these sites it was possible to classify the individuals by taking into consideration the leaf morphology, as the lamina becomes longer and relatively narrower when the plants get older. However, due to the fact that there were considerable differences in the morphology of the leaves between the sites, it was impossible to establish a general classification scheme to be used at all the sites, based exclusively on leaf morphology, as e.g. that of Linkola (1935). At a few sites with a thick moss carpet, the individuals were grouped into only two classes:

A: Individuals with a rhizome of uniform thickness throughout its length or increasing only slightly in thickness from its distal to its proximal end (presumably largely corresponding to Class I + II + III).

B: Individuals with a rhizome which is distinctly thicker for part of its length (presumably largely corresponding to Class IV + V + VI).

Except for Class I and the distinction flowering/non-

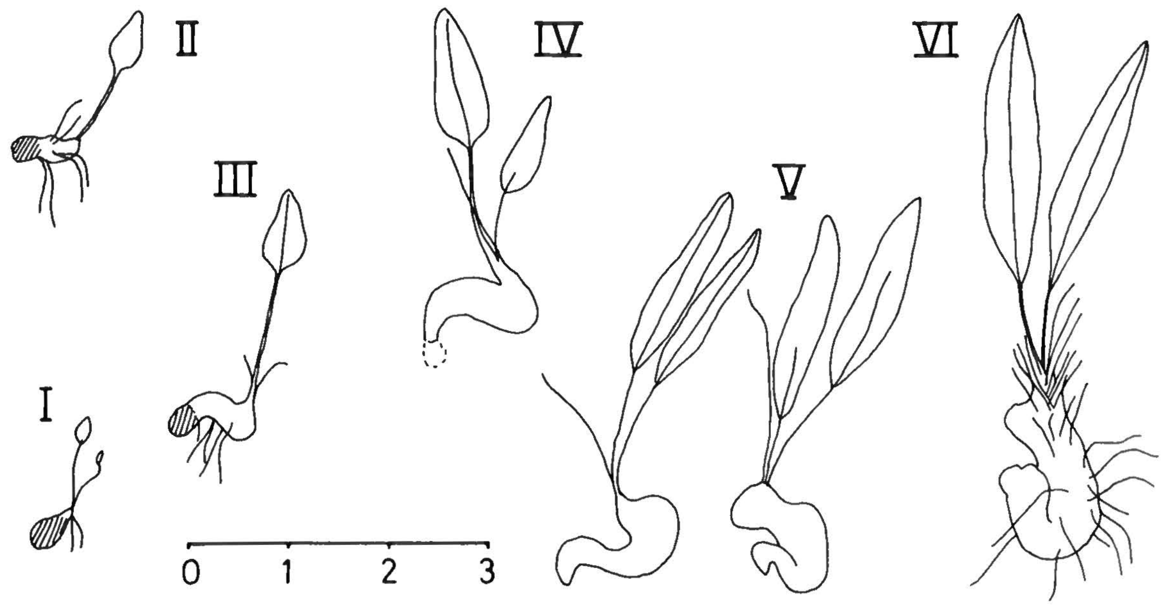

Fig. 1. Sketch of individuals of *Polygonum viviparum* from Site 1, belonging to Class I–VI: For description of the classes see p. 5.

flowering individuals, most of the characters used for the classification are quantitative, but with some practice it was possible to classify any plant with a relatively high degree of certainty.

On the basis of the classification and enumeration of the plants, for each site the percentage distribution of the individuals on the six classes was calculated, together with the number of Class I-individuals as per cent of the number of bulbils, and the number of flowering individuals as per cent of the total number of individuals in those classes where flowering occurred.

After classification and enumeration, the plants were dried in paper bags at 60° C. After drying, the attached dead plant remains from previous years were removed and rhizomes, leaves and stalks weighed separately. On the basis of these weighings, the mean weight of (rhizome + leaves + scapes) per individual was determined for flowering individuals, and for non-flowering individuals belonging to those classes in which flowering occurred.

For each site the weight of the bulbils which had been produced by the flowering individuals was determined by multiplying the number of bulbils (cfr. above) with a mean bulbil weight, found by counting and weighing all the bulbils from ten typical individuals from the site in question. The weight of the bulbils produced by the plants from the sample plots was not determined since the bulbils tended to become detached during the digging up and transport.

The sites investigated

The sites, which were investigated are briefly characterized below; the soil profile is described and the dominating plant species mentioned. The nomenclature of the vascular plants follows Böcher, Holmen & Jakobsen (1966). Tables 1 and 2 give additional information about edaphic conditions, topography, and microclimate.

Site 1. Slightly SE-sloping area, 15 m a.s.l., dominated by *Dryas integrifolia, Polygonum viviparum, Salix glauca*, and *Vaccinium uliginosum*. Arctic Brown soil, the upper 5 cm with thickly woven plant roots. Fig. 5.

Site 2. NE-exposed solifluction stripes, rather steep, 125 m a.s.l. Vegetation sparse; almost pure mineral soil. Fig. 2.

Site 3. Stripes of vegetation, dominated by *Rhacomitrium* sp., *Betula nana, Cassiope tetragona, Dryas integrifolia*, and *Vaccinium uliginosum*. On the same slope as Site 2. Approx. 5 cm of Arctic Brown soil, thickly woven plant roots, with gradual transition to the mineral soil. Fig. 2.

Site 4. Snow-bed along watercourse, 125 m a.s.l. Rich in herbs with *Salix herbacea* dominating. 1–2 cm of earth rich in organic matter with gradual transition to the mineral soil.

Site 5. Willow-scrub, 0.5–1 m high, 70 m a.s.l. Vegetation cover at 10 cm height and more 90%. Dominating species *Salix glauca* and *Equisetum arvense*.

The soil very rich in organic matter, blackish, with thickly woven plant roots.

Site 6. Relatively dry site, 125 m a.s.l., with a thick carpet of *Hylocomium splendens* and *Aulacomnium palustre*, and scattered willows, 25–35 cm high. Vegetation cover at 10 cm height and more 75%. Soil very rich in organic matter and porous, thickly woven with plant roots.

Site 7. Steep, but stable scree slope, S-exposed, 100 m a.s.l. *Vaccinium uliginosum.* Arctic Brown soil, the uppermost 3–5 cm thickly woven with plant roots.

Site 8. Moist, slightly hummocky area, 40 m a.s.l. *Luzula parviflora, Salix glauca.* Soil very rich in organic matter.

Site 9. Steep, SW-exposed herb-slope, 50 m a.s.l. Dominating species *Alchemilla glomerulans, Equisetum arvense*, and *Salix glauca.* Vegetation cover at 10 cm height and more 90%. Arctic Brown soil, thickly woven with plant roots. Fig. 5.

Site 10. Gravelly hollow, 160 m a.s.l. *Carex bigelowii* and *Salix herbacea.* The soil with a high gravel content.

Site 11. Fell-field vegetation, 180 m a.s.l. Dominating species *Cassiope tetragona, Dryas integrifolia, Salix glauca* and *Vaccinium uliginosum.* 3–4 cm of Arctic Brown soil, thickly woven with plant roots, with gradual transition to the mineral soil.

Site 12. Snow-bed, 140 m a.s.l., becomes free of snow only late in the season. *Equisetum arvense, Polygonum viviparum*, and *Salix herbacea.* Fig. 3.

Site 13. Moist carpet of moss (*Philonotis tomentella*) in cleft, late to be freed of snow, 90 m a.s.l. *Equisetum arvense* the only noteworthy vascular plant. 1–2 cm of more or less decomposed plant remains over mineral soil.

Site 14. Wet area, 2 m a.s.l., dominated by *Carex rariflora* and *Salix Arctophila.* The upper 10 cm of soil fairly homogeneous, with only a low organic matter content near the surface. Fig. 4.

Site 15. Slightly S-sloping area, 10 m a.s.l. *Polygonum viviparum* and *Salix glauca.* Soil rich in organic matter and thickly woven with plant roots. Fig. 5.

Site 16. Heath, 70 m a.s.l. *Empetrum hermaphroditum, Salix glauca,* and *Vaccinium uliginosum.* Raw humus.

Site 17. Moist heath, 20 m a.s.l. *Betula nana, Empetrum hermaphroditum,* and *Vaccinium uliginosum.* Raw humus.

Site 18. Fen, 25 m a.s.l. *Oncophorus wahlenbergii, Carex rariflora* and *Salix arctophila*. More or less undecomposed plant remains with gradual transition to the mineral soil.

Site 19. Dry, stony area, 35 m a.s.l. *Polygonum viviparum* and *Salix herbacea*. Arctic Brown soil.

Site 20. Heath, 35 m a.s.l. *Betula nana, Empetrum hermaphroditum*, and *Vaccinium uliginosum* dominating. 5–8 cm of raw humus over sandy mineral soil.

Site 21. Heath, 35 m a.s.l. *Betula nana, Carex rupestris, Empetrum hermaphroditum*, and *Vaccinium uliginosum* dominating. Arctic Brown soil, the uppermost 1–2 cm thickly woven with plant roots.

Fig 2. Sites 2 and 3, situated on an NE-exposed slope. Site 2 comprises the solifluction stripes which are almost free of vegetation, while Site 3 comprises the more stable stripes between them which are covered with a thick mat of *Rhacomitrium* sp., with *Betula nana, Cassiope tetragona, Dryas integrifolia* and *Vaccinium uliginosum.*

Site 22. Willow-scrub, 1 m high, 25 m a.s.l. Cover of *Salix glauca* at 10 cm height and more 90%. Soil rich in organic matter, thickly woven with plant roots.

Site 23. Steep, dry, S-exposed slope, 150 m a.s.l., with heath vegetation: *Empetrum hermaphroditum, Salix glauca,* and *Vaccinium uliginosum.* No *Polygonum viviparum*. Arctic Brown soil.

Site 24. Fen, 25 m a.s.l., with *Eriophorum angustifolium* and *Calliergon sarmentosum.* Submerged peat. A water sample was taken. *Polygonum viviparum* did not occur at this site.

Site 25. Along temporary watercourse, 650 m a.s.l. *Polygonum viviparum, Salix glauca,* and *Salix herbacea* dominating.

Site 26. Thick carpet of *Aulacomnium turgidum*, with *Equisetum arvense* and *Salix glauca*, 25 m a.s.l.. 5–8 cm of raw humus with gradual transition to reddish silt.

Site 27. Dry, SW-exposed slope, 575 m a.s.l. *Har-*

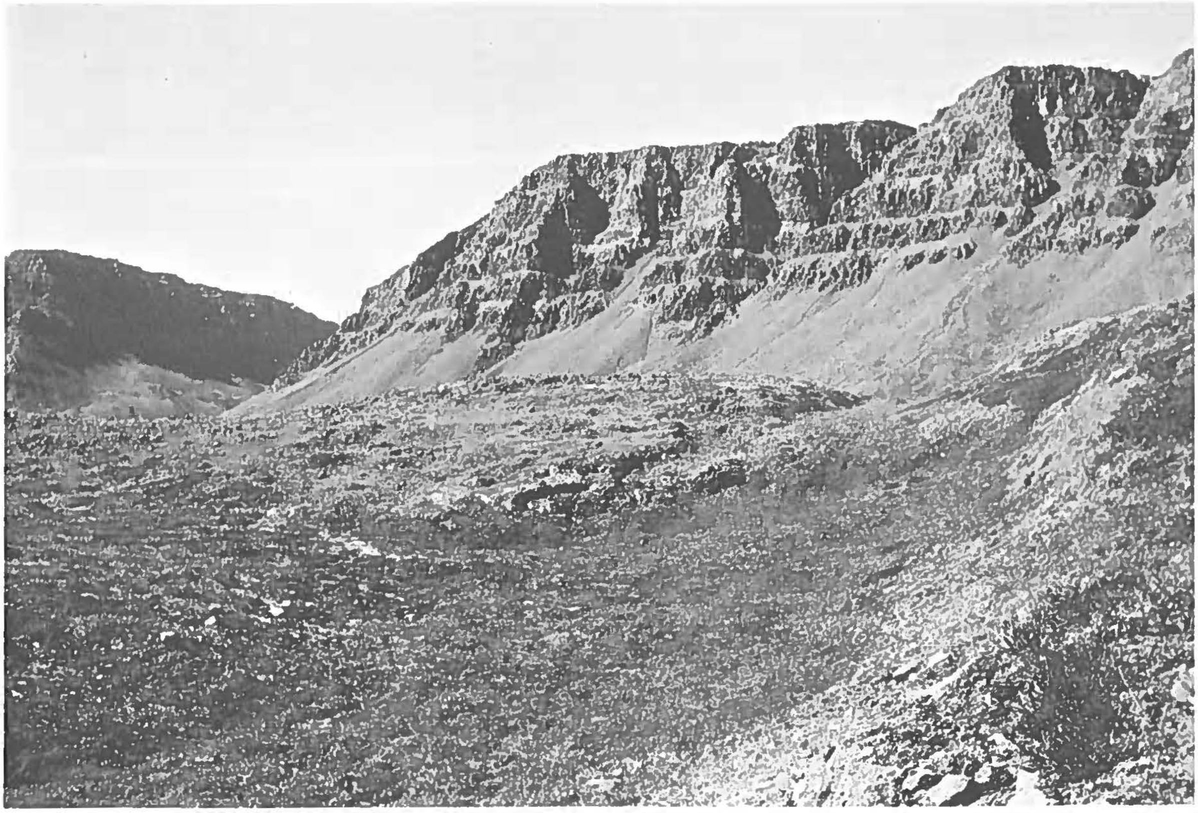

Fig. 3. Site 12, as seen from the south. The site, a snow-bed only late to be free of snow, is situated in the depression in the middle of the picture, and dominated by *Equisetum arvense, Polygonum viviparum,* and *Salix herbacea.* The depression is bordered by fell-field with scattered vegetation. In the background Lyngmarksfjeld.

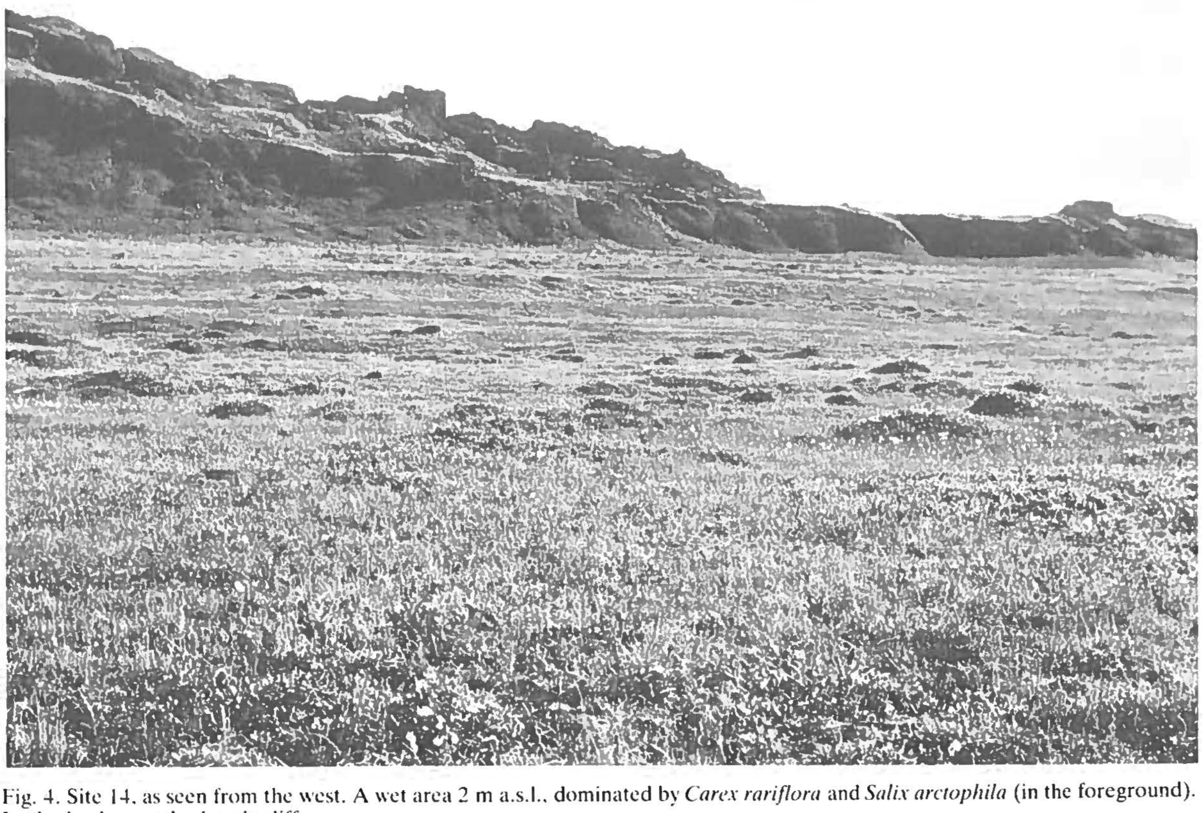

Fig. 4. Site 14, as seen from the west. A wet area 2 m a.s.l., dominated by *Carex rariflora* and *Salix arctophila* (in the foreground). In the background a basalt cliff.

rimanella hypnoides, Salix glauca, and *S. herbacea*.

Site 28. Moist, slightly NW-sloping area with some solifluction, 500 m a.s.l.. *Carex lachenalii, Salix glauca*, and *S. herbacea* dominating.

Site 29. Dry, gravelly, steep W-exposed herb-slope, 125 m a.s.l., with *Polygonum viviparum, Salix glauca*, and *S. herbacea* dominating. Approximately 5 cm of Arctic Brown soil thickly woven with plant roots, with gradual transition to the gravelly mineral soil.

Site 30. Moist, temporarily water-filled hollows in a heath, 35 m a.s.l.. *Drepanocladus badius* and other mosses, *Carex bigelowii, Polygonum viviparum*, and *Salix arctophila*. A few cm of soil with more or less decomposed plant remains, with gradual transition to sandy mineral soil.

Site 31. W-exposed rock-ledge near the harbour in Godhavn, 10 m a.s.l., strongly eutrophicated.

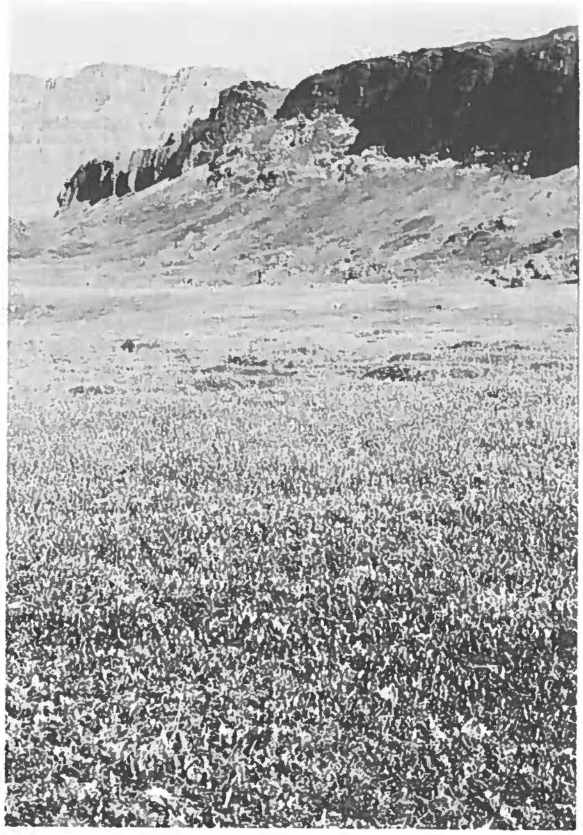

Fig. 5. Østerlien, E of Arctic Station. In the foreground Site 15, a slightly S-sloping area dominated by *Polygonum viviparum* and *Salix glauca*. In the middleground (on the terrace) Site 1, dominated by *Dryas integrifolia, Polygonum viviparum, Salix glauca*, and *Vaccinium uliginosum*. These two sites had – together with Site 31, see Fig. 6 – the highest number of individuals of *Polygonum viviparum* and the highest production of bulbils per unit area. – In the background, to the left (on the scree), Site 9, a steep, SW-exposed herb-slope dominated by *Alchemilla glomerulans, Equisetum arvense*, and *Salix glauca*.

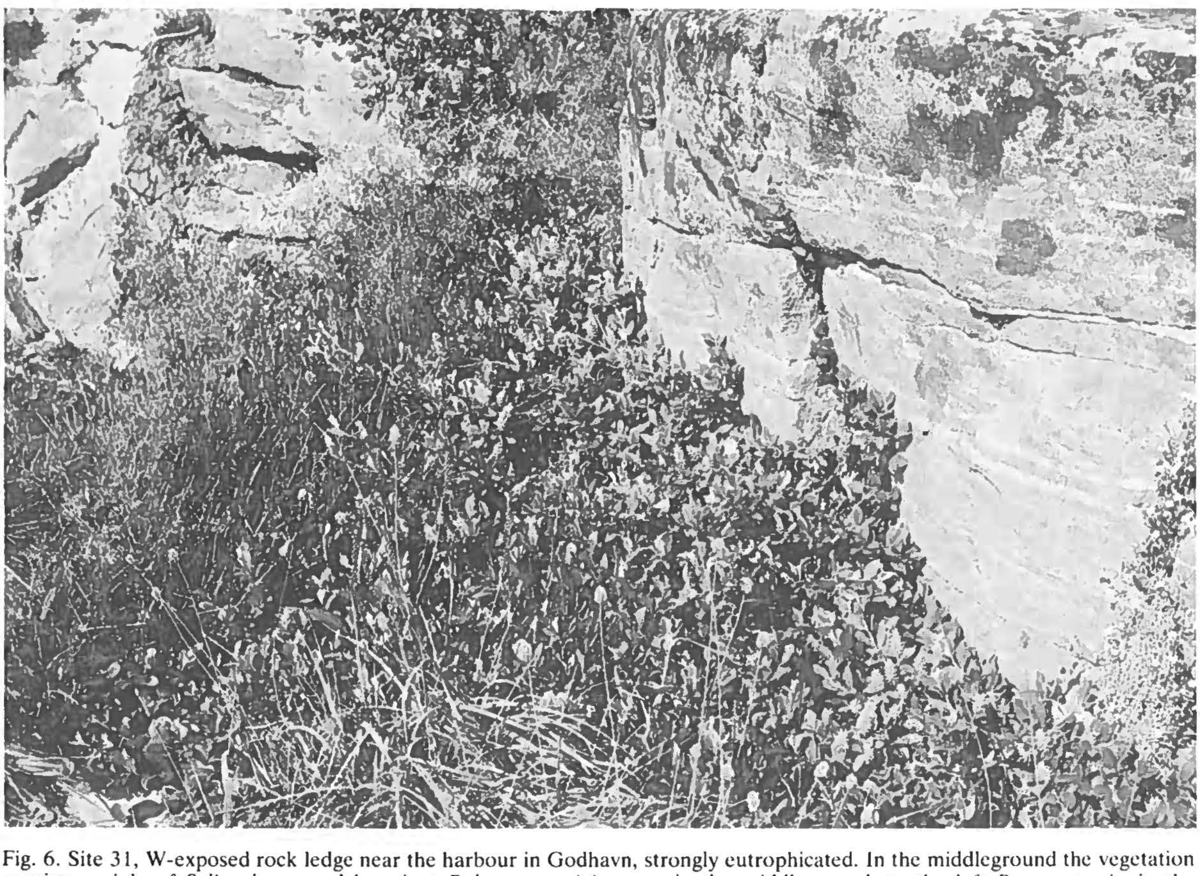

Fig. 6. Site 31, W-exposed rock ledge near the harbour in Godhavn, strongly eutrophicated. In the middleground the vegetation consists mainly of *Salix glauca* and luxuriant *Polygonum viviparum*; in the middleground, to the left *Poa pratensis*, in the foreground *Alopecurus alpinus*.

Polygonum viviparum and *Salix glauca*. Vegetation cover at 10 cm height and more 90%. Arctic Brown soil. Fig. 6.

Site 32. Area with gravelly soil, with signs of frost heaving and free of vegetation, 180 m a.s.l. Close to Site 11. Soil gravelly-silty, no profile. No *Polygonum viviparum*.

Site 33. Dense grass mat with *Alopecurus alpinus*, close to Site 31. Vegetation cover at 10 cm height and more 100%. Arctic Brown soil, thickly woven with grass roots. No *Polygonum viviparum*.

Site 34. Snow bed, only free of snow very late in the season, dominated by small mosses, 175 m a.s.l. The soil gravelly-clayey.

Site 35. Hummocky area along small lake 15 m a.s.l., influenced by seepage water. Dominating species *Plagiomnium medium* ssp. *curvatum*, *Sphagnum squarrosum*, *Alopecurus alpinus*, *Eriophorum angustifolium*, *Poa arctica*, *Polygonum viviparum*, and *Salix glauca* The soil rich in organic matter and very porous, thickly woven with plant roots.

Soil conditions

Table 1 gives the results of the soil analyses. It appears that all parameters show a large variation.

In South Greenland, the occurrence of *Polygonum viviparum* shows weak positive correlation with the pH of the soil, in a material where pH ranges from 3.7 to 7.0 (own unpublished investigations). However, within the pH range of the present material, 5.1 to 7.3, there is hardly any correlation with pH.

In the present material, the loss on ignition ranges from 4 to 86% of soil dry weight. The loss on ignition is of no direct importance to the plants, but of great indirect significance since the organic matter content largely determines the water and cation capacity of the soils in the investigation area. A high loss on ignition results on sites where the production of organic matter is high (e.g. Site 5, 6, and 22) or the decomposition is restrained (e.g. Site 18), or both.

Soil water is of great significance for the occurrence, survival and development of *Polygonum viviparum*. On a volume basis, the water content ranges from 5 to 67%, while in relation to the content of organic matter it ranges from 43 to 816 g/100 g loss on ignition. At Site 29, wilted plants belonging to Class I, II, III, and IV occurred, and older plants showed distinctive drought injury. At Site I wilted plants belonging to Class IV and VI occurred, and at Site 15 wilted Class I-individuals. It is concluded therefore, that soil water becomes a minimum factor at sites where the soil water content in periods of drought falls below approximately 25%, or approximately 175 g/100 g loss on ignition (cfr. Table 1).

The range of the C/N-ratio is so wide (7.7–23) that, directly or indirectly it must be of importance to the development of the plants and the competition conditions in the vegetation. At all those sites where the vegetation was luxuriant, the C/N-ratio was about 10, or less. Porsild (1932) quotes that *Polygonum viviparum* is nitrophilous and that it is markedly favoured when growing near human habitations.

The content of exchangeable K in the soil ranges from 80 to 860 ppm, the highest values were found on scree slopes under basalt cliffs. The content of 0.2 N H_2SO_4-soluble P ranges from 22 to 800 ppm, the highest values were found at strongly eutrophicated sites and at sites situated high above sea level. The content of both K and P is thus rather high, but the values are comparable to those reported by Hansen (1967) from the Faeroes, where the climate is temperate oceanic and the bedrock is basalt. In Godhavn, the bedrock is basalt only in about half of the investigation area, but the majority of the sites is influenced by material carried by wind and water from the basalt area. It cannot on the basis of the present material be established to what degree the content of K and P influences the occurrence, survival, and development of *Polygonum viviparum*, e.g. through the competition conditions in the vegetation. However, it should be mentioned that the occurrence of *Polygonum viviparum* was found not to be correlated with the content of P in a material from South Greenland, where the content of P ranged from 10 to 1,820 ppm, mean 157 ppm (own unpublished investigations).

S^{--} occurred at Site 18 below a depth of 6.5 cm, at Site 24 below a depth of 7 cm. However, the formation of S^{--} is certainly a very slow process at the prevailing low soil temperatures (cp. Table 2, Site 18), and as the activity of the plant roots is delimited to the uppermost few centimeters of the soil profile, the content of S^{--} is scarcely a limiting factor at any of the sites.

Other environmental parameters

Table 2 gives the time of the melting of the snow for nine sites in the three year period 1970–72, and some soil temperatures from 1972. At the individual sites, these parameters vary from year to year (Petersen 1977 and unpublished data), but the values given can contribute to place the sites in relation to each other. At the remaining sites, topography, soil water content, and vegetation yield information about microclimate and snow cover. Table 1 gives the exposition, inclination, and direction of all the sites. The height above sea level ranges from 2 to 650 m; however, only three of the sites (25, 27, and 28) are situated more than 200 m a.s.l. For 19 sites situated on sloping ground, the inclination ranges from 6° to 34°, and the direction of the slope from 44° to 293°. 16 sites are situated on level terrain. Two of these (31 and 33) are so close to large rocks (Fig. 6) that microclimatically they should be considered as steep slopes facing 260°.

The occurrence of *Salix herbacea* at Sites 4, 8, 10, 12, 13, 19, 25, 27, 28, 29, and 34 indicates that every winter

Table 1. Edaphic conditions and topography at 35 sites with or without (*) Polygonum viviparum. The values from Site 24 have been measured on a water sample. - : not measured. For the grouping of sites see p.12 - 13.

Group	Site	pH	soil water content % by volume	g/100 g l.o.i.	C/N	exchangeable K, ppm	extractable P, ppm	loss on ignition (l.o.i.), %	slope, degrees	direction of slope, degrees	height a.s.l., m	bulk density
1	32*	6.7	26	213	21	310	58	8	0	-	180	1.5
1	10	6.4	28	259	14	350	101	11	0	-	160	1.0
1	2	7.1	21	215	20	230	85	7	22	44	125	1.6
2	34*	7.1	28	227	18	430	126	9	13	255	175	1.4
2	13	7.2	33	432	16	350	89	10	0	-	90	0.8
2	28	-	37	-	-	-	-	-	10	293	500	1.6
2	12	6.5	34	221	11	470	73	15	11	143	140	1.0
2	4	6.2	27	203	15	510	67	15	7	135	125	0.9
2	25	7.3	27	409	14	230	352	13	29	163	650	0.5
3	24*	6.8	-	-	-	0.02	-	-	0	-	25	-
3	18	5.5	67	816	16	80	218	69	0	-	25	0.1
3	14	6.7	55	536	19	660	422	8	0	-	2	1.2
3	8	6.6	44	511	8.6	-	61	64	0	-	40	0.1
3	30	5.6	21	461	9.9	120	28	4	0	-	35	1.1
3	17	5.8	22	362	10	120	41	65	0	-	20	0.1
3	26	6.6	21	335	18	470	800	45	9	181	35	0.1
4	21	6.5	30	194	14	630	45	45	0	-	35	0.3
4	11	6.8	27	195	13	390	85	12	6	283	180	1.1
4	16	5.6	20	230	16	590	82	25	8	188	70	0.4
4	15	6.8	24	167	13	230	166	16	9	188	10	0.9
4	1	7.0	22	118	19	160	122	24	6	146	15	0.8
4	3	6.0	11	119	16	390	54	27	22	44	125	0.3
4	20	5.2	7	115	23	120	22	85	0	-	35	0.1
4	19	5.1	6	43	14	200	32	35	15	290	35	0.4
5	7	6.7	12	126	11	660	76	19	23	195	100	0.5
5	23*	5.6	21	164	19	820	222	26	31	199	150	0.5
5	9	5.8	9	110	9.6	860	74	17	34	220	50	0.5
5	29	6.2	7	79	13	550	77	9	23	242	125	0.8
5	27	6.9	17	-	16	160	580	-	25	152	575	0.8
6	35	5.3	27	550	8.5	-	120	86	0	-	15	0.1
6	31	5.9	36	252	11	310	546	43	0	(260)	10	0.3
6	33*	5.7	22	211	9.1	230	562	38	0	(260)	10	0.3
6	5	5.6	11	188	8.4	350	78	75	0	-	70	0.1
6	6	6.8	5	142	7.7	270	170	84	0	-	125	0.1
6	22	6.3	7	122	11	510	222	84	14	205	25	0.1

Table 2. Soil temperatures (absolute maximum and highest minimum temperature, at the soil-litter interface and at a depth of 10 cm, in the growing period of 1972) and the earliest and latest date of disappearance of snow in 1970-72. Nine sites with Polygonum viviparum.

Group	Site	soil-litter interface		10 cm depth		snow disappearance	
		highest min.	absolute max.	highest min.	absolute max.	earliest date	latest date
2	12	3.0	19.5	4.0	10.0	June 3	July 18
3	17	3.0	17.5	4.5	9.5	May 11	June 17
3	18	4.5	12.0	5.0	8.0	May 24	June 8
4	21	3.5	25.0	7.0	10.5	May 11	June 7
4	11	4.5	21.0	6.5	11.5	May 2	June 7
4	16	2.0	19.5	4.5	10.5	May 11	June 7
4	20	2.0	21.0	6.5	12.0	May 24	June 7
5	7	5.5	27.5	7.0	12.5	May 2	May 20
6	5	2.0	18.5	4.5	6.5	May 20	June 1

these sites are covered by a thick snow layer, while the occurrence of *Carex rupestris* at Sites 1, 3, 7, 11, and 21 shows that in the winter these sites are covered by a thin layer of snow which melts early in the spring.

Microclimate and snow cover are those environmental factors in the Arctic which generally have the greatest significance for the composition and development of the vegetation. Within the investigation area, *Polygonum viviparum* does not seem to be exacting as regards thickness of the snow cover, but duration of the growing period may become a limiting factor (cp. p. 16).

Grouping of the sites

None of the environmental factors mentioned above exert their influence on the vegetation isolated from other factors, and quite a number of important factors have not or have only partly been studied. Besides, several of the factors investigated show limiting values at a number of sites. Because of this it has not been attempted to correlate further the occurrence and population structure of *Polygonum viviparum* with any single environmental factor. Instead, the sites have been assigned to six groups which have been defined with emphasis on those factors assumed to be limiting. In Tables 1–5, the sites have been arranged according to this grouping.

1. Sites with soil movement (32, 2, 10). These sites are also characterized by high pH and C/N-ratio, high bulk density, and low content of organic matter. – Site 28, which has been included in group 2, is closely related to the sites in Group 1.

2. Sites where the snow is late in disappearing (34, 13, 28, 12, 4, 25). These sites are also characterized by high pH-values, while the content of organic matter and bulk density is rather variable. Regarding the soil temperature, these sites are not less favourable than e.g. the sites in Group 4, but the growing period is shorter (cp. Table 2, Site 12). The soil water content is not limiting.

3. Sites with waterlogged soil (24, 18, 14, 8, 30, 17, 26). The sites in this group are rather different, except for a high soil water content, and – as a result – low soil temperatures (cp. Table 2, Site 18). Sites 24, 18, 14, and 26 have a high C/N-ratio, Sites 8, 30, and 17 a low C/N-ratio. Except Site 14 and 26, the sites must be considered poor in K and P.

4. Well-drained sites on level or slightly sloping ground (21, 11, 16, 15, 1, 3, 20, 19). Characteristic for these sites is the dry soil and the high C/N-ratio. The vegetation indicates that there is a rather large variation in the time at which the snow melts and in soil temperatures (cp. Table 2, Site 11, 16, 20, and 21), pH and other edaphic factors. However, the conditions cannot be considered extreme at any of the sites.

5. Steep slopes, exposed to the sun (7, 23, 9, 29, 27). These sites are characterized by a low soil water content during periods of drought. The melting of the snow takes place early in the year and the soil temperatures may increase to high values (Table 2, Site 7). Differences in the vegetation show that the thickness of the snow cover is very different between the sites. It is estimated that the thickness of the snow increases from Site 7, through Site 23, 9, and 29, to Site 27. The content of organic matter in the soil is rather low, and the highest concentration of exchangeable K occur at these sites.

6. Sites where competition for light is an important factor (35, 31, 33, 5, 6, 22). This group includes sites where the degree of cover of the vegetation at 10 cm height and more exceeds 25%. Sites 5, 6, and 22 are covered with willow scrub, Site 33 with a dense mat of *Alopecurus alpinus*. Under the willow scrubs, not only is the light climate less favourable than in the open, but the soil temperature is also lower (Table 2, Site 5). At Site 31 the vegetation consisted almost exclusively of *Polygonum viviparum* (and *Salix glauca*), while at Site 35 the vegetation was a mixed grass-herb vegetation, of the same height as *Polygonum viviparum*.

These sites are further characterized by a high con-

Table 3. Total number of individuals of Polygonum viviparum, number of Class I-individuals, number of flowering individuals and number of bulbils produced, per m^2, at 30 sites. Also, the lowest and highest number of individuals found in any of the sample plots, and the total area of the sample plots, for each of the sites.
- : not determined.

Group	Site	total number	Class I-individuals	flowering individuals	bulbils	individuals in sample plots min.	individuals in sample plots max.	area of plots, m^2
1	10	140	0	14	254	8	25	0.8
1	2	35	3	1	20	0	15	2.5
2	13	880	-	10	-	-	-	0.2
2	28	50	8	10	-	0	20	2.1
2	12	260	14	68	-	17	39	0.5
2	-	52	8	10	204	0	21	2.5
2	25	1,460	340	240	-	146	146	0.1
3	18	16	0	0	0	0	7	2.5
3	14	380	60	10	183	25	54	0.3
3	8	355	-	15	28	27	53	0.4
3	30	765	55	70	685	73	80	0.2
3	17	178	41	24	278	5	29	0.8
3	26	242	20	12	104	6	37	0.5
4	21	293	18	23	303	18	36	0.4
4	11	28	1	3	56	0	10	2.5
4	16	1	13	1	14	0	15	2.5
4	15	2,860	330	490	7,940	286	286	0.1
4	1	2,590	140	850	17,870	259	259	0.1
4	3	4	0	1	12	0	3	2.5
4	20	33	1	1	13	0	23	2.5
4	19	427	17	183	2,533	32	46	0.3
5	7	6	0	2	74	0	5	2.5
5	9	15	1	11	384	0	7	2.5
5	29	680	10	270	8,505	62	74	0.2
5	27	122	13	20	440	0	52	1.0
6	35	467	163	47	2,403	25	68	0.3
6	31	2,490	1,720	190	14,930	249	249	0.1
6	5	105	-	0	0	0	21	1.0
6	6	76	-	8	157	1	27	1.5
6	22	7	-	1	10	0	4	2.5

tent of organic matter, and by a low bulk density due to a highly porous soil. The C/N-ratio is low, and the soil water content either relatively high, or seepage water occurs at some depth. – Site 9, which has been included in Group 5, is closely related to the sites in Group 6.

Population structure of *Polygonum viviparum*

Table 3 shows that there is a considerable variation as regards several absolute values: total number of individuals, number of Class I-individuals, number of flowering individuals, and number of bulbils produced per square metre. This applies both to the material as a whole, and to the individual groups of sites. However, as regards certain relative values referring to the population structure there are in a number of cases a high degree of similarity between the sites within a group (the distribution of the individuals between classes, Table 4; the ratio Class I-individuals/number of bulbils produced; and the percentage of flowering individuals in those classes where flowering occurs, Table 5). This applies also to certain features characterizing the plants,

Table 4. Distribution between classes (I - VI) of individuals of Polygonum viviparum on 30 sites. The values in the table give the numbers as per cent of the total number of individuals, N. For description of the classes, see p. 5 - 6 and Fig. 1.

Group	Site	I	II	III	IV	V	VI	N
1	10	0	6	0	5	5	85	111
1	2	9	20	9	7	10	45	89
2	13		53		22	11	14	176
2	28	16	13	12	12	7	41	102
2	12	5	5	6	9	18	55	130
2	4	15	5	3	11	24	32	132
2	25	23	16	16	12	33		146
3	18	0	3	8	13	16	61	38
3	14	16	13	22	25	16	8	114
3	8		42			58		144
3	30	7	24	9	6	17	46	153
3	17	23	13	4	12	6	43	142
3	26	8	20	29	12	31		121
4	21	6	7	6	4	17	60	117
4	11	2	3	0	7	2	87	61
4	16	3	21	6	30	21	18	33
4	15	12	16	12	4	5	51	286
4	1	5	14	9	18	24	29	259
4	3	0	17	0	0	0	83	12
4	20	4	1	14	8	13	59	83
4	19	4	6	10	10	18	52	128
5	7	0	0	0	0	6	94	16
5	9	5	8	0	0	0	87	39
5	29	1	4	26	12	57		136
5	27	11	12	16	16	11	34	122
6	35	31	21	16	18	16		160
6	31	69	14	7	5	3	2	249
6	5		40			60		105
6	6		22			78		113
6	22		17			83		118

e.g. the mean weight of the vegetative parts of the flowering individuals, and the number of bulbils produced per plant (Table 3).

In the following section, the characteristics of the populations of *Polygonum viviparum* in each of the six groups of sites are given. Partly on the basis of the results in Tables 3–5, the significance of the environment for the establishment, growth, development, survival, and production of bulbils is discussed.

By way of introduction, a comment should be made about the distribution of the individuals between the classes. Assuming that the recruitment of new individuals and the environment do not vary significantly from year to year, a single time-specific life-table, as shown for the individual sites in Table 4, may be used for calculation of the mortality of a population. However, these assumptions do not hold for *Polygonum viviparum* in the investigation area. None the less, the table permits certain qualitative conclusions. If the number of individuals is highest in Class I, and decreases significantly with age, it can be deduced that there is a persistently rather high mortality in all age classes. If, on the other hand, the number of individuals in all (or some of) the younger age classes is zero or low, while there is an accumulation of individuals in the older age classes, it must be assumed that the phase of establishment is especially critical, i.e. that establishment takes place only in certain years when conditions are favourable, and that mortality is low among the old plants.

As already mentioned, *Polygonum viviparum* was absent from five of the sites investigated. In all these cases, the species was found a few metres away; which shows that the absence cannot be due to lack of bulbils, but must be due to establishment having been prevented by an unfavourable environment. The occurrence of *Polygonum viviparum* at sites 5 and 18 (105 and 16 individuals per m² respectively), where the species did not flower, shows that a population can be maintained exclusively on the basis of bulbils produced elsewhere. Ryvarden (1971) found that in the alpine zone at Finse in Norway 209 out of 1,045 diaspores caught in a stream trap were of *Polygonum viviparum*. It is characteristic in Godhavn that in the spring there was a strong melt-water run-off at the two sites where the number of individuals per unit area was highest, Sites 15 and 1 (2,860 and 2,590 individuals per m² respectively). Most probably bulbils carried by melt-water originate at sites situated on sloping terrain where the production of bulbils is high, but where the number of recently established individuals is relatively low, e.g. Site 29 and 19, where the production of bulbils amounted to 8,505 and 2,533 per m² respectively. – Gelting (1937) suggested that bulbils might be dispersed by the wind in the winter, but the data of Ryvarden (1975) shows that at least at Finse the number of bulbils dispersed in this way is insignificant.

1. Sites with soil movement. Site 32 is an area with frost heaving where there is a relatively fine grained, almost pure mineral soil, devoid of vegetation. Raup (1969) quotes that *Polygonum viviparum* in the Mesters Vig area in East Greenland has a wide tolerance to soil movements due to frost. However, the tolerance of the species must nevertheless be limited. Fig. 7 shows how the individuals of *Polygonum viviparum* at a site a few hundred metres from Site 32 occurred exclusively along the edge of the frost circles.

At Site 10, the rhizomes of the older plants were vertical and protracted, indicating that the plants had been repeatedly covered with gravel. A figure in Hartz & Kruuse (1911, l.c. p. 400) shows how the rhizome of plants growing in sand dunes may become similarly protracted. Old plants seem to grow apace with a cer-

Table 5. Relative values, referring to the population structure, and features characterizing the flowering individuals of Polygonum viviparum, for each of the 30 sites in the investigation area where the species occurred. - : parameter not determined. + : Class I-individuals occurred on the site, but the exact number could not be determined, or the number of bulbils could not be determined. ÷ : Class I-individuals, subsidiary flowering individuals, absent from the site. N: number of flowering individuals.

Group	Site	Class I-individuals, % of bulbils produced	classes, in which flowering occurred	% flowering individuals in classes where flowering occurred	mean d.w. of rhizome + leaves + scape of flowering individuals, g	mean d.w. of non-flowering individuals in classes where flowering occurred, g	mean number of bulbils per flowering individual	N	mean number of bulbils per spike	mean number of spikes per flowering individual
1	10	0	VI	12	0.08	0.07	18± 7	11	19	1
1	2	16.3	VI	8	0.11	0.09	16	3	16	1
2	13	+	VI	8	-	0.05	-	-	-	1
2	28	+	VI	48	-	0.04	-	-	-	1
2	12	+	V,VI	35	-	0.06	-	-	-	1
2	4	3.9	V,VI	35	0.15	0.08	22± 7	23	22	1
2	25	+	V,VI	50	-	-	-	-	-	1
3	18	÷	÷	-	-	-	-	-	-	-
3	14	32.7	V,VI	11	0.06	0.04	18	3	18	1
3	8	-	-	-	-	-	11	1	11	1
3	30	9.3	V,VI	17	0.08	0.06	10± 7	14	10	1
3	17	14.9	V,VI	28	0.12	0.10	12± 6	18	12	1
3	26	19.2	V,VI	16	0.09	0.09	9± 4	6	9	1
4	21	5.8	V	10	0.13	0.08	13± 4	9	13	1
4	11	0.7	VI	15	0.12	0.08	17± 7	8	17	1
4	16	2.9	V,VI	15	0.18	0.11	17	2	17	1
4	15	4.2	V,VI	32	0.20	0.14	16± 6	50	16	1
4	1	0.7	V,VI	62	0.14	0.12	22± 8	83	19	1.1
4	3	÷	VI	20	0.25	0.13	15	2	15	1
4	20	9.3	V,VI	5	0.14	0.07	11	3	11	1
4	19	0.7	V,VI	62	0.14	0.10	14± 6	13	14	1
5	7	÷	VI	40	0.55	0.25	31± 16	6	24	1.3
5	9	0.2	VI	82	0.55	0.40	37± 20	26	27	1.4
5	29	0.1	V,VI	70	0.36	0.28	33± 18	47	25	1.4
5	27	3.0	VI	49	0.18	0.12	21± 7	20	21	1
6	35	6.8	V,VI	56	0.64	0.20	49± 26	14	33	1.6
6	31	11.5	IV,V,VI	73	0.94	0.08	114± 46	13	41	2.6
6	5	+	÷	-	-	-	-	-	-	-
6	6	+	-	-	0.23	-	24± 5	10	24	1
6	22	÷	-	-	0.12	-	7	2	7	1

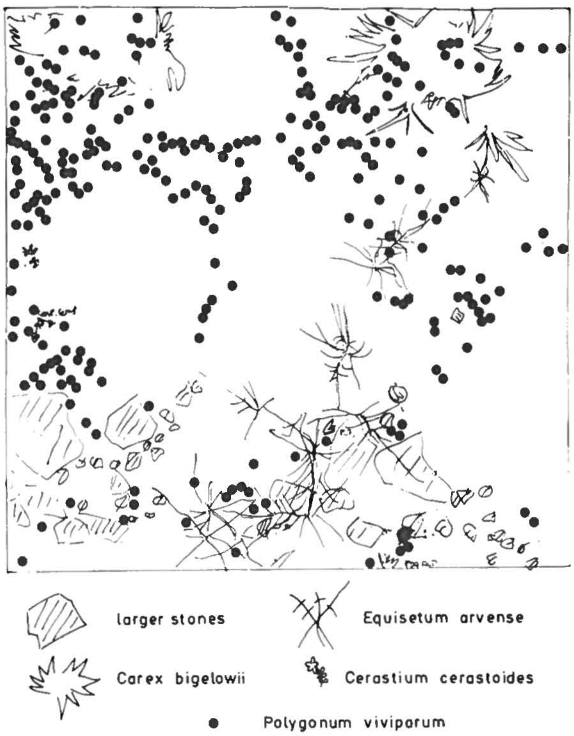

Fig. 7. The distribution of individuals of *Polygonum viviparum* within 1 m² in an area with frost circles. Note that the plants grow almost exclusively along the edge of the circles, where the material is coarsest and the movement of the soil weaker. Fell-field on Lyngmarksfjeld, 250 m a.s.l..

tain covering, whereas establishment seems to be difficult under these conditions. Practically none of the individuals at Site 10 belonged to Class I–V.

Solifluction and soil creep do not seem to damage *Polygonum viviparum* as much as frost heaving, since the individuals at Site 2 (Fig. 2) were more evenly distributed between the classes. This is in accordance with Seidenfaden's observation that *Polygonum viviparum* occurred with a frequency of 56%, at a locality with slowly moving soil on Clavering Ø (Seidenfaden 1931).

Due to the low number of sites in this group it is impossible to point out any general features of the populations of *Polygonum viviparum*, except that the plants were small and that flowering individuals were infrequent and all belonged to Class VI.

2. Sites where the snow is late in disappearing. Site 34 is the innermost part of a snow-bed (described by Lauridsen & Thostrup 1974). *Polygonum viviparum* did not occur here. At all the other snow-bed sites – 13, 28, 12, 4, and 25, where Site 13 shows the highest and Site 25 the lowest floristic similarity with Site 34 – quite a number of Class I-individuals occurred. This shows that in general the conditions in the snow-beds are favourable for the establishment of *Polygonum viviparum*. The plants were, however, relatively small, and flowering individuals belonged either to Class VI or – in those snow-beds where the snow disappeared earliest – Class V and VI. At some of the sites they made up half the number of individuals in those classes where flowering occurred. Apart from Site 4, the bulbils were not yet ripe at the time of investigation. Whether the bulbils at a given site will be capable of ripening must depend on the time of the melting of the snow and the time when the growth period ends. Both these dates vary from year to year. The variation is largest as regards the time of melting of the snow; at Site 12 the difference over a three year period amounted to almost six weeks.

It was possible to obtain a picture of the production of bulbils at only one of the snow-bed sites because the bulbils were generally not yet ripe. At Site 4, the flowering individuals had one spike each, with a mean of 22 bulbils.

3. Sites with waterlogged soil. *Polygonum viviparum* did not occur at Site 24, the wettest and at the same time the site poorest in mineral nutrients. At Site 18 which was likewise very wet and poor in nutrients, there occurred no Class-I-individuals, as opposed to the remaining sites. Generally the plants at these sites were small, though increasing in weight from the wettest to the driest sites. At Site 18 there was a predominance of old individuals, but even in Class VI the plants were extremely small (mean weight 0.1 g) and did not flower. At the other sites, flowering individuals occurred both in Class V and VI. They had one spike and means ranging from 9 to 18 bulbils per plant. The percentage of flowering individuals in those classes where flowering occurred ranged from 11% at Site 14 to 28% at Site 17, which was one of the driest sites in this group.

4. Well-drained sites on level or slightly sloping ground. *Polygonum viviparum* occurred at all these sites. There were no Class I-individuals at Site 3, and only a few at the other sites. The plants were medium sized, and there was a predominance of old individuals. Where flowering occurred, the percentage of flowering individuals in those classes ranged from 5 to 62. At the majority of the sites, the flowering individuals had only one spike, and means ranging from 11 to 22 bulbils per plant.

5. Steep slopes, exposed to the sun. At Site 23, a steep, SW-exposed slope (where furthermore the C/N-ratio was the highest of this group of sites), *Polygonum viviparum* did not occur, at the other sites there were no or only a few Class I-individuals. The plants were large; the mean weight of the flowering individuals ranged from 0.8 g at Site 27 (which was situated 575 m a.s.l. and strictly speaking a dry snow-bed) to 0.55 g at Site 7 and 9. At the sites belonging to this group, almost all the flowering individuals belonged to Class VI, but they made up a large part of the indi-

viduals in those classes where flowering occurred, from 40 to 82%. The mean number of spikes per flowering individual ranged from 1 to 1.4, the mean number of bulbils from 21 to 37.

6. Sites where competition for light is an important factor. At site 31, *Polygonum viviparum* had not been able to become established. Due to the thick moss- and litter layer in the willow scrubs, Site 5 and 6, it was only possible to state – though not to quantify – the occurrence of Class I-individuals. Similarly, it was impossible, both at these two sites and at Site 22, to classify the individuals; consequently, a number of parameters could not be determined. The plants were rather small, and flowering was absent or occurred only rarely, even in old individuals. Moreover, the development and size of the individuals seemed to vary with the light conditions.

At Site 31 and 35, the competition for light was intraspecific, or with species which were about as high as *Polygonum viviparum.* There were many Class I-individuals, and the distribution of the individuals on the classes indicates that the mortality of the population is rather high throughout the life span of the plants (a similar population structure, with a predominance of recently established individuals, was described by Linkola (1935) in a dense meadow vegetation in Eastern Finland). The flowering individuals were large, at Site 35 a mean of 0.64 g, at Site 31, 0.94 g. At Site 31 a few plants had reached a height of 50 cm. The percentage of flowering individuals was high in the classes where flowering occurred, 56 and 73% respectively. Similarly a considerable number of bulbils were produced per plant, 49 and 114. Altogether, Site 31 was the site where the flowering individuals reached their optimum development: flowering occurred already in Class IV, the mean number of spikes per plant amounted to 2.6 (the maximum being 5), and the germination of the bulbils took place while they were still attached to the scape.

Porsild (1932) quotes that *Polygonum viviparum* is favoured when growing near human habitations, where the specimens become much taller and produce a greater number of flowers and bulbils than in natural vegetation. Site 31 is an example of this. Sørensen (1941) mentions that the flowering of *Polygonum viviparum* is determined by the vegetative development of the plants, so that spikes do not normally develop if fewer than three leaves per year are formed. Table 5 shows that there is a significant agreement between the mean weight of the flowering individuals and the mean number of bulbils produced per plant. A large number of bulbils per plant is result of a combination of a high number of bulbils per spike and an increased number of spikes per flowering individual.

There seems to be a marked difference between the sites as regards the weight which the plants must obtain before flowering (however, at each individual site the weight of the flowering individuals was higher than the weight of the non-flowering individuals in the same class). Probably the plant weight and the production of bulbils should not be considered in isolation, but in connection with the frequency of flowering of the individual plant. The highest percentages of flowering individuals in those classes where flowering occurred, were noticeably at those sites where the plants were largest.

It is assumed (p. 5) that each of the classes I–V corresponds to an age class of one year, while Class VI comprises individuals which are over five years old. According to this, flowering does not occur at Site 31 before the fourth year, at the majority of the sites not before the fifth year, and at a few sites not before the sixth year (Table 5). Sørensen (1941) mentions that the young plants (on Ella Ø, in East Greenland) take a number of years of reinforcement before flowering. For many years they produce but one small leaf each year. In Finland, Linkola (1935) found that the plants in a meadow passed a youth stage of five years duration before flowering. In the absence of competition the whole development was completed in one year. However, in Godhavn, even at the most favourable sites, this is scarcely possible under the prevailing climatic conditions.

Observations of parasites, symbionts, and herbivores

No systematic observations in this field were carried out, but casual observations were noted. The smut *Sphacelotheca ustilaginea* D.C. which destroys the bulbils, occurred at Sites 1, 4, 6, 8, 9, 29, and 31, where 2, 12, 9, 83, 8, 14, and 28% of the spikes respectively were infected. For comparison, Stepanova & Tomilin (1971) found in some plant communities in the tundra on the Taimyr peninsula that the percentage of infected spikes of *Polygonum viviparum* ranged from 14 to 45. The rust *Puccinia bistortae* D.C. was observed on the leaves of *Polygonum viviparum* at Site 7, the Ascomycete *Rhytisma bistortae* at Sites 1, 15, and 19. *Sclerotinia polygonum-vivipari* Eckbl. (on shed bulbils) was found at Sites 15, 16, and 35. It was, however, impossible to estimate to what degree the parasitic fungi influence the growth and development of the host plant, except in those cases where the bulbils are destroyed.

Hesselmann (1900) has described the ectotrophic mycorrhiza formed by *Polygonum viviparum.* In the investigation area, ectotrophic mycorrhiza was noted at Sites 14, 27, 28, and 35, but probably occurs more commonly.

Among the herbivores, ptarmigan, arctic hare and snow bunting occur in the investigation area, but their influence of the populations of *Polygonum viviparum* is unknown.

Biomass and production of bulbils on an area basis

In the light of the role of *Polygonum viviparum* as an important constituent of many arctic vegetation types and food for a number of animals, the biomass of the species, and the distribution of the biomass of the flowering individuals on rhizome, leaves, scapes and bulbils was determined, as well as the number of bulbils produced at a number of the sites investigated.

The dry weight of the standing crop was determined at eighteen sites. It ranged from 0.6 g per m^2 (at Site 3) to 281 g per m^2 (at Site 15), mean 49.2 g, median 10.2 g per m^2.

At twelve sites with ripe bulbils the distribution of the biomass of the flowering individuals was as follows: rhizome 35–82%, leaves 12–24%, scapes 2–30%, and bulbils 2–18%.

At twenty-four sites, the weight of bulbils produced ranged from less than 0.1 to 35.0 g per m^2, mean 4.9 g, median 0.3 g per m^2. At only seven sites the weight of the bulbils was over 1.0 g per m^2: Site 9 (1.4 g), Site 19 (3.9 g), Site 35 (9.4 g), Site 15 (18.1 g), Site 29 (18.3 g), Site 31 (27.0 g) and Site 1 (35.0 g).

It appears that the mean values of both the biomass and the bulbils produced is to a considerable degree influenced by the occurrence of a few particular sites, which are characterized either by the occurrence of large individuals of *Polygonum viviparum* with a large number of bulbils per individual, or by the occurrence of a large number of smaller individuals with a lower number of bulbils per individual. At the majority of the sites, both the biomass and the production of bulbils was rather low. Taking into account the frequency of the different types of sites in the investigation area, it appears that the biotopes where the biomass and the production of bulbils is high are of subordinate importance. Thus the median, rather than the mean values should be considered representative for the investigation area.

Conclusion

Polygonum viviparum occurs in the investigation area in a very high proportion of the vegetation types where vascular plants are represented. There is, however, a large variation between the sites as regards the density of individuals, the population structure, the biomass per unit area, the size of the flowering individuals, and, consequently, the production of bulbils. The main reason for this variation is that individuals of *Polygonum viviparum* of a different age are in a different way and to a different degree influenced by the environmental conditions.

The establishment of plants from bulbils is primarily limited by desiccation of the soil in periods of drought, and by soil movements. The chance of establishment is particularly low at dry, steep slopes. Frost heaving prevents establishment, while the effect of solifluction and soil creep seems to be less serious. Establishment is most successful at moist sites.

The survival of the growing plants is reduced by intra- and interspecific competition for light. Furthermore, young plants seem to be more sensitive to unfavourable moisture conditions than old ones.

The rate of development and the final size of the plants vary in accordance with the nutrient status of the soil, the microclimatic conditions, and the duration of the growing season. At sites with a low content of P or exchangeable K, the plants do not even reach a size at which they can flower. A short growing season and physical stress (soil movement) seem to delay the time of flowering and result in a reduction in size of the flowering individuals. The plant size is also reduced where the C/N-ratio is low. As the number of bulbils produced per flowering individual varies in accordance with plant weight, the number of bulbils produced per plant is reduced where the plant size is reduced.

The largest plants are found at sites where the microclimate is favourable, the nutrient status high, and the soil relatively moist. However, also at dry sites, the plants may become fairly large, adult individuals being less sensitive to drought than recently established ones. At these sites, *Polygonum viviparum* is to a lesser degree than at the moist sites exposed to competition for light from taller species, e.g. *Salix glauca*.

A higher or lower proportion of the bulbils produced are destroyed by parasitic fungi or eaten by birds or mammals. The number of bulbils available for the continuation of the population at a given site also depends on the number of bulbils transported to or from the surrounding areas, and is thus determined in part by topography and surface run-off.

At only a few sites in the investigation area *Polygonum viviparum* is a dominant constituent of the vegetation, as expressed by the density of individuals, or the biomass per unit area. These sites are characterized by an abundant supply of bulbils, produced either at or outside the site, and environmental conditions which are favourable to the establishment of plants, and to growth and development of the plants once they are established.

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