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Scientific note

Three-year vegetation change in the Arctic environment as observed in a permanent plot in Ny-Ålesund, Svalbard

Satoru Kojima

Faculty of Arts and Sciences, Tokyo Woman's Christian University,
2–6–1, Zempukuji, Suginami-ku, Tokyo 167-8585 (kojima@lab.twcu.ac.jp)

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Abstract: A permanent plot was established in 1997 to monitor vegetation development in a recently abandoned coal mine in Ny-Ålesund, Svalbard. A 1 m × 1 m quadrat was set up and further divided into one hundred small 10 cm × 10 cm cells. All the vascular plants occurring in the plot were recorded for each of the 100 cells. In 1999, the plot was revisited and examined for occurrences of vascular plants. Further, in 2002, the plot was re-surveyed and all the vascular plants were measured for their coverage. Data were compared and coverage change over the past three years was detected. Vascular plants significantly increased, indicating that the vegetation succession is currently in progress.

key words: Arctic, monitoring, permanent plot, vascular plants, vegetation succession

The objectives of this study are: 1) to monitor the chronosequential vegetation development that is taking place in an abandoned coal mine site in Ny-Ålesund, Svalbard, 2) to assess the rate of vegetation development, and 3) to characterize the pattern of vegetation succession in the Arctic environment. The study site is located approximately 1 km northeast of Ny-Ålesund. The town of Ny-Ålesund was once the site of extensive excavation of coal from the early 1910s (Arlov, 1994). The mining operations almost ceased in the late 1950s after successive accidents, and completely shut down in 1962. Since then, a large area of former coal mine sites has been abandoned (Fig. 1) and the natural vegetation succession has started there. After *ca*. 40 years, some vascular plants have established themselves, forming sporadic patches here and there.

In 1997, a permanent plot (marked VSOP: Vegetation Succession Observation Plot) 1 m × 1 m in size was established in an abandoned coal mine site to observe the vegetation succession and to monitor future vegetation change (Fig. 2). Details of the plot site and its general environmental characteristics are fully discussed in Kojima (2002). Following is a brief summary of the environmental characteristics. Climate: a typical tundra climate, *i.e.*, *ET* type of climate after Köppen with mean annual temperature −5.4℃, mean monthly temperature of the warmest month 6.2℃, that of the coldest month −17.3℃ (Morimoto *et al*., 2000); dominant geology: Carboniferous to Permian limestone and dolomite; surficial geology: prevalently of glacial till and outwash with gently undulating relief topography (Hjelle, 1993); vegetation: typical

Fig. 1. A vast area of deserted coal mining site on the outskirts of Ny-Ålesund.

Fig. 2. A permanent plot established in a deserted coal mine to monitor vegetation recovery and succession.

tundra with low vegetative cover.

In order to assess vegetation cover in the initial stage of the observations in 1997, the plot was divided into 100 small cells (sub-quadrats) 10 cm × 10 cm square. All the sub-quadrats were grid-coordinated with a combination of letters and numbers such as A-5, C-3, etc. For each sub-quadrat, all the vascular plants were recorded. Their coverage was assessed and recorded as the initial stage of the observation. In the cover assessment, only vascular plants were taken into the account. Bryophytes and lichens were important components of the arctic vegetation. But they were not subjected to this assessment because of the practical difficulty of determining species and assessing coverage immediately in the field.

In 1999, the plot was revisited. Vegetation change was closely examined and recorded. The recorded data were compared with those of the 1997 (Kojima, 2002). At the same time in 1999, all the vascular plants occurring in the subquadrats were assessed for their cover area in cm^2. Each sub-quadrat was further divided into 100 micro-cells of 1 cm × 1 cm by overlaying a frame with a 1-cm mesh screen. All the vascular plants were then scrupulously checked for occurrences in the 1-cm^2 micro-cells. A value of 1 cm^2 was given to any species as long as it was found in the micro-cell. A total coverage of species for the plot was then obtained by summing all the cm^2 values. In 2002, the plot was visited again and all the vascular plants were checked by the same procedure for their coverage change in the three years since 1999.

In the plot, a total of nine vascular species were identified both in 1999 and 2002. Neither new emergence nor disappearance of species took place during the period. Table 1 shows the cover area change of the nine species. Vegetative cover substantially increased in three years. In 1999, the total coverage of nine species was 1929 cm^2; it became 3647 cm^2 in 2002, *i.e.*, a 189% increase in three years. Vascular vegetation covered 19% of the total area of the plot in 1999, increasing to 36% in 2002.

As for individual species, all the species but *Pedicularis* sp. substantially increased their cover. *Salix polaris* Wahlenb. showed the highest cover both in 1999 (801 cm^2) and 2002 (1454 cm^2), which increased by 182%. The second highest species was *Polygonum viviparum* L. with cover of 366 cm^2 in 1999, which increased to 900 cm^2 in 2002, *i.e.*, a 246% increase. *Saxifraga oppositifolia* L. also showed a relatively large cover 446 cm^2 in 1999, which increased to 812 cm^2 in 2002. All of the other 5 species (*Silene acaulis* L., *Carex misandra* R.Br., *Luzula confusa* Lindeb., *Juncus biglumis* L., and *Saxifraga caespitosa* L.) increased from 1999 to 2002. Of nine species *Juncus biglumis* showed the greatest increase. It exhibited a drastic increase from 2 cm^2 to 33 cm^2, 16.5 times, for the three years. *Pedicularis* sp. stayed the same. Figure 3 is a graphical presentation of the three-year changes of the species.

Table 1. Plant cover change for the past three years in the permanent plot.

Species	Coverage (cm^2)		Rate of increase
	1999	2002	
Salix polaris	801	1454	1.82
Polygonum viviparum	366	900	2.46
Saxifraga oppositifolia	446	812	1.82
Silene acaulis	130	209	1.61
Carex misandra	119	141	1.18
Luzula confusa	58	90	1.55
Juncus biglumis	2	33	16.50
Saxifraga caespitosa	4	5	1.25
Pedicularis sp.	3	3	1.00
Total	1929	3647	1.89

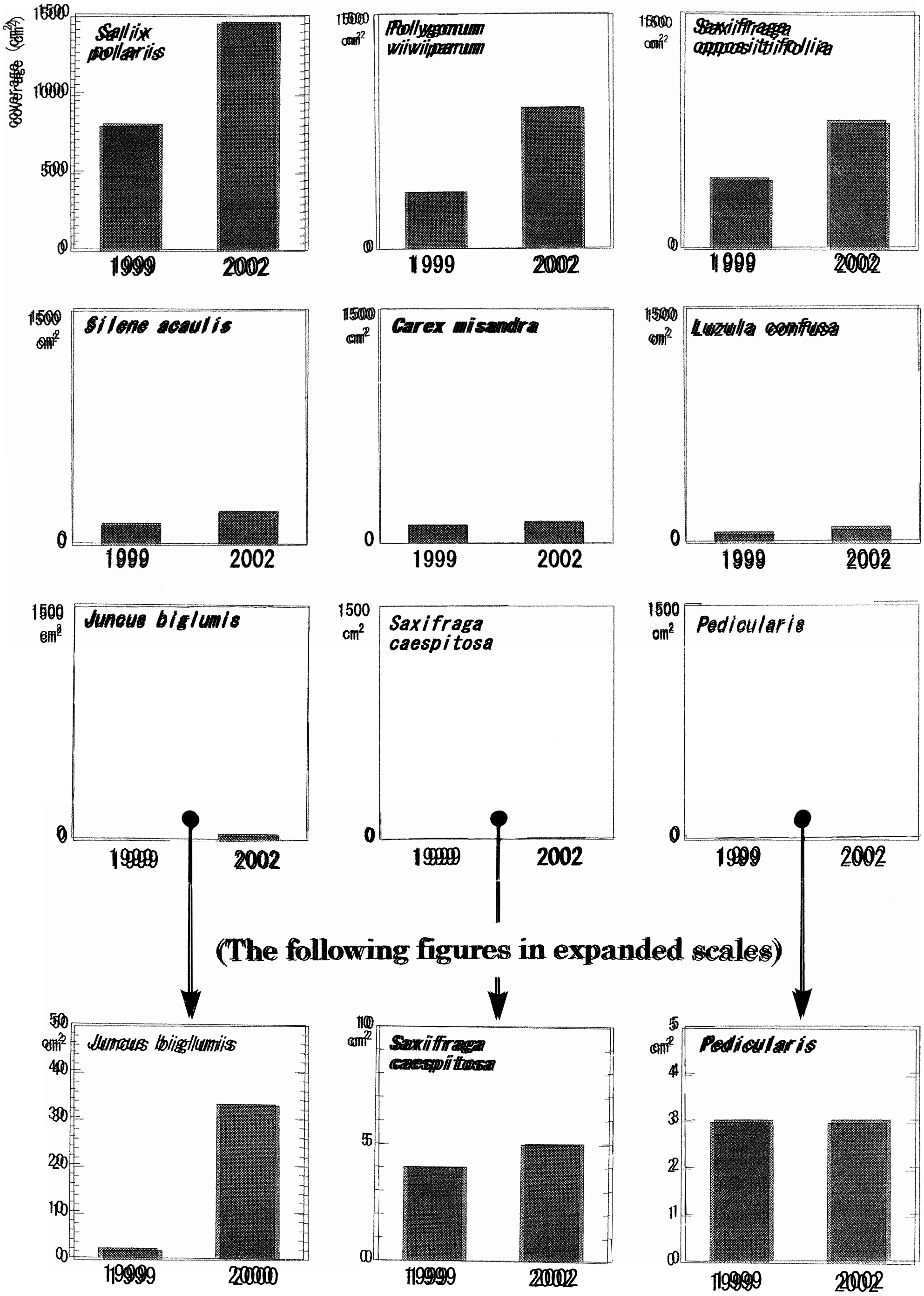

Fig. 3. Diagrams illustrating increase of species cover change from 1999 to 2002.

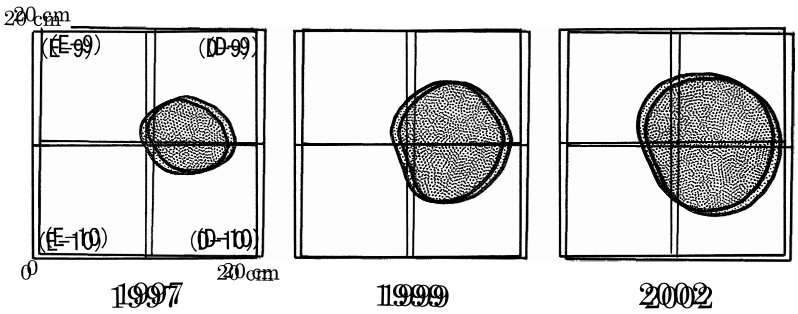

Fig. 4. Actual sketches of a *Silene acaulis* cushion expansion from 1997 to 2002.

In terms of mode of cover increase, there are three kinds of pattern, *i.e.*, vegetative shoot elongation, tuft/cushion expansion, and seed germination. The cover increase of *Saxifraga oppositifolia* is attributed to the shoot elongation while that of *Silene acaulis* is due mainly to cushion expansion, and that of *Juncus biglumis* primarily to seed germination. Figure 4 illustrates how a cushion of *Silene acaulis* expanded for the past five years.

After forty years of desertion of the coal mine site, the vegetation succession appears to be still rapidly progressing. Total vegetative cover as well as that of individual species substantially increased even over the short period of the observation. However, during the three-year observation, neither new participation nor disappearance of vascular species took place in the plot. This seems to imply that there will not be any drastic change in floristic composition in the future no matter how the vegetation succession advances. This appears to be one of the unique features of the arctic vegetation, called "non-directional and species non-replacement succession" by Bliss and Peterson (1992).

The course of chronosequential vegetation development may differ considerably from place to place in response to local environmental conditions such as microclimate, topographical position, geological and soil characteristics, soil moisture status, and so forth, even under the uniform macroclimatic condition of the Arctic. The results of the present study, therefore, do not necessarily apply to all the vegetation succession in the Arctic environment. However, such a study as this will provide some basic information as to vegetation development, as one of the case studies actually performed in the Arctic environment.

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