２－６　THE RELATIONSHIP OF WATER QUALITY RESTORATION AND PLANTS RE-ESTABLISHMENT IN BOG MIRE CONSERVATION

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INTRODUCTION

The correlation between vegetation and element content in mire waters has been well studied in Europe and North America, as well as recently in Japan. The poor rich vegetation gradient in peatlands in defined by the low number of characteristic species present in Sphagnum dominated peatlands relative to the high number of characteristic species found in brown moss dominated peatlands. This poor rich gradient is also related to overall species richness and reflects an underlying hydrotopographical and chemical gradient often referred to as the ombrotrophic minerotrophic gradient, from ombrogenous (rain-fed) mineral-poor conditions to geogenous (ground water-fed) mineral-rich conditions. The modern concepts of bog and fen should represent a composite of vegetational, chemical and hydro-topographical components. Bogs are poorest in number of species and ombrotrophic, while fens are richer in species and minerotrophic.

In Sarobetsu Mire, the ombrotrophic-minerotrophic gradient is found along east-west direction, and shown clearly at the surface by the invasion of exotic, non bog-mire plant, *Sasa spp*. This invasion occurs at the western side of the mire, even though some ombrotrophic plants such as: *Rhynchospora alba, Molinia cearulea*, *Lycopodium annotinum*, and *Ilex crenata* are still found accompanying this species. An effort to restore the water chemistry regime into its original state, i.e. ombrotrophic, was carried out by installation small dams along the natural channel. The re-establishments of the natural plats by this effort were then studied in relevance to the restoration of water chemistry.

METHODS

To retain rain water in the natural channel, we installed two 1.5 m-wide, 2 m-deep dams in November 2000: an upper and a lower dam, 6.3 m downstream of the upper. We established surface water sampling points at each dam (dA and dB) and at the downstream side the lower dam (dBd). Water samples were collected during the period 2000 to 2003. Surface water samples were collected from 30 cm-diameter installed PVC pipes directly by polyvinyl jug after rinse. Ground water samples were collected from PVC pipes which were installed in the vicinity of dam A by suction after initially purging the water for each sampling period to obtain fresh water samples. PVC pipes were 7.5 cm in diameter and had a permanent basal cap. Each pipe contained one set of 5.0 mm-diameter holes across the pipe along a 20-cm length of pipe. This set of holes centered at a depth of 0.5, 1.0, 1.5, 2.0 or 2.5 m relative to the mire surface. In between sampling periods the PVC pipes were capped to avoid contamination. The chemical analyses were conducted according to analytical methods recommended by the Hokkaido Branch of the Japan Society of Analytical Chemistry (2000). These were studied: pH, EC, alkalinity 4.3 Bx, dissolved organic carbon (DOC), main inorganic ion (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}), SiO_2, dissolved reactive phosphorus (DRP), dissolved phosphorus (DP), ammonia (NH^+-N), nitrite (NO_2^--N), nitrate (NO_3^--N), and dissolved nitrogen (DN). The water chemistry of the dam site was then compared with the data of three areas from previous research: a point of natural conditions (point E), and two points of disturbed conditions (points WW and NC).

In the summer of 2003, cover abundance of each species at the dams and the three comparator sites (E, WW, and NC) was recorded using 1 m x 2 m rectangles which were latticed into 50 subquadrats of 20 cm x 20 cm. The scales of 1 to 5 were used, with the scale 5 given to the species found in more than 75% of the total subquadrats, scale 4 for 50-75%, scale 3 for 25-50%, scale 2 for less than 25% and scale 1 given to the species found in only one subquadrat. Scale (+) is given for a single plant found in the rectangle.

RESULTS AND DISCUSSION

The summary of water chemical analysis is shown in Table 1. Data from 0.5 m and 2 m depths were omitted from the table, considering their similarities with the data from 1 m and 1.5 depths, respectively. The effect of the dams in restoring water quality is obvious. In almost all respects, surface and pore waters until 1 m depth have been restored to its natural condition. This makes perfect sense: Since the bog mire water originates from rainfall, its hydrochemical characteristics should be similar to those of rainwater. This result shows that the restoration of water chemistry in degraded bog mire can be achieved by "recharging" the mire with rainwater, since the original water source of the bog mire is precipitation.

Table 1 Chemical properties of water at the dam site (2000-2003) compared with those at points E, WW and NC (1993 - 2000).

Sampling point	dB	dBd	dA			E			WW			NC		
Depth (m)	0	0	0.0	1.0	1.5	0.0	1.0	1.5	0.0	1.0	1.5	0.0	1.0	1.5
n	8	12	12	3	9	29	28	29	23	25	25	16	16	18
pH	4.3	4.4	4.3	4.6	6.2	4.28	4.51	4.59	4.16	5.23	5.24	4.94	6.74	6.59
EC (µS/cm)	72.2	72.3	72.9	88.7	147.6	85.3	73.2	66.2	87.6	99.1	102.8	118.1	350.8	347.8
4.3Bx (meq/L)	0.04	0.03	0.02	0.07	1.04	0.02	0.04	0.05	0.01	0.17	0.23	0.55	3.06	3.18
D-N (mg/L)	1.48	1.37	1.41	2.35	3.65	0.78	0.74	0.83	1.24	4.23	4.90	2.10	4.45	4.64
NH_4^+-N (mg/L)	0.33	0.13	0.06	0.13	2.39	0.08	0.09	0.15	0.22	2.82	3.64	0.83	3.62	3.52
NO_2^--N (mg/L)	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
NO_3^--N (mg/L)	0.02	0.01	0.01	0.03	0.02	0.04	0.07	0.05	0.11	0.02	0.01	0.06	0.07	0.09
D-P (mg/L)	0.043	0.031	0.016	0.025	0.089	0.007	0.009	0.006	0.033	0.017	0.016	0.034	0.039	0.035
DRP (mg/L)	0.021	0.011	0.002	0.006	0.033	0.003	0.002	0.002	0.009	0.012	0.005	0.020	0.031	0.018
SiO_2 (mg/L)	1.6	1.5	1.1	6.1	24.4	4.31	4.78	4.22	1.91	22.35	21.35	12.43	37.35	35.45
Na^+ (mg/L)	7.53	7.49	7.22	11.84	20.26	8.90	8.02	7.29	9.73	10.80	9.57	14.33	29.65	27.88
K^+ (mg/L)	0.36	0.55	0.25	0.93	1.40	1.12	0.52	0.54	0.80	1.43	1.47	2.22	5.68	5.25
Ca^{2+} (mg/L)	0.78	0.94	1.06	1.53	1.07	1.68	1.57	1.05	1.53	0.69	0.69	2.36	9.63	9.29
Mg^{2+} (mg/L)	1.49	1.58	1.55	1.90	5.54	1.52	1.43	1.17	1.83	0.85	0.84	3.65	11.27	11.21
Cl^- (mg/L)	10.53	11.46	10.69	12.98	12.18	17.23	15.98	14.01	17.52	17.34	17.21	18.28	17.07	15.17
SO_4^{2-} (mg/L)	2.39	1.73	1.85	0.85	0.71	1.11	0.89	0.65	3.95	0.67	0.69	2.04	0.97	0.88
DOC (mg/L)	18.72	19.34	18.49	39.59	44.92	29.95	24.97	21.00	18.91	48.65	41.35	27.52	8.93	9.27

Notes: Due to space limitations and considering their similarities with the data from 1 m and 1.5 m depths, data of 0.5 m and 2 m depths are not shown.

The re-establishments of some natural bog mire plants are also achieved by the installation of the dams. The vegetation list (Table 2) shows the plant species and their cover abundance at each sampling point. In the vicinity of the dam site, *Miliniopsis japonica* dominates along the natural channel, where *Carex lasiocarpa var. occultans* dominates the surroundings of the upper dam. *Drepanocladus exannulatus* was also found along the upper stream of the upper dam, where *Sphagnum riparium* dominates the area between the two dams. Based on the reports of The Ministry of the Environment of Japan (2002) and Hotes et al. (2001), some vegetations found at the dam site such as *Sphagnum riparium* and *Miliniopsis japonica* are main vegetation species in

Sarobetsu mire and also other coastal mires in Hokkaido, and that *Carex lasiocarpa* var. *occultans* accompany these species.

Table 2 Plant communities and their species composition at each sampling point. See text for cover abundance estimates.

E	*Myrica gale var. tomentosa*	1	dA	*Carex lasiocarpa var. occultans*	4
	Empetrum nigrum	4		*Moliniopsis japonica*	2
	Chamaedaphne calyculata	1		*Drepanocladus exannulatus*	5
	Oxycoccus quadripetalus	2		*Scirpus fluviatilis*	+
	Drosera rotundifolia	2		*Sphagnum riparium*	4
	Rhynchospora alba	3			
	Carex lasiocarpa var. occultans	3	dB	*Moliniopsis japonica*	+
	S. papillosum Lindb	2		*Sasa kurilensis*	2
	S. nemoreum Scop.	3			
	Andromeda polifolia	+	WW	*Sasa kurilensis*	5
	Rubus chamaemorus	+		*Ilex crenata var. paludosa*	2
	Solidago virgaurea var. *asiatica*	+		*Ledum palustre var.diversipilosum*	1
	Parnassia palustris	+		*Rhynchospora alba*	2
	Hasta rectifplia	+		*Moliniopsis japonica*	1
	Hemerocallis dumortieri	+		*Lycopodium annotinum*	+
			NC	*Sasa kurilensis*	5

Canonical correspondence analysis ordination (Fig. 1) reveals the relationships of water chemistry characteristics and each species. The first two axes of CCA already explained 82.3% of the variance of all data, therefore we may neglect the next two axes which explained less variance and did not appropriately reflect the gradient among the plant communities.

Along axis 1, the site scores decreased from the degraded area through dam B and point WW toward the natural area and also dam A. Sodium showed the largest positive correlation with this arrangement followed by SO_4^{2-}, DP, pH, SiO_2, DOC, and Ca^{2+}, where only DON showed the negative correlation. Along the ascending direction of axis 2, a gradient from the stagnant water communities (*Rhynchospora alba*) to the moving water adapted plants (*Drepanocladus exannulatus)* was found. SO_4^{2-} concentration positively correlated with this arrangement, where other parameters were negatively correlated with smaller magnitudes.

The first axis seems to explain better about the restoration of water chemistry in relation with its effects to the vegetation, where point E and dam A with relatively similar water characteristics with the natural condition, have similar response. As for the dam B, its difference in response to this axis seems to be owing to its hydrological regime, i.e. water level and its fluctuation.

This result showed that even though the restoration of water chemistry succeeded to re-establish some raised bog vegetations, it does not exactly revert back the plant communities toward its original stage. The different in hydrological regime seems to play an important role to this process, where the restoration by damming does not seem to restore the hydrological regime. On the degraded area (i.e., points WW, NC, and also the dam site) soil has poor water-holding capacity with high permeability. Much of this may due to the low levels of organic matter present. Organic matter that formed from dead plants creates protective mulch that reduces soil erosion and water evaporation and acts as a sponge that absorbs water in the soil. The damming may restore and stabilize the water level at damaged mire in a short span of time, but the alteration of soil properties which related to the hydrological regime may needs longer period.

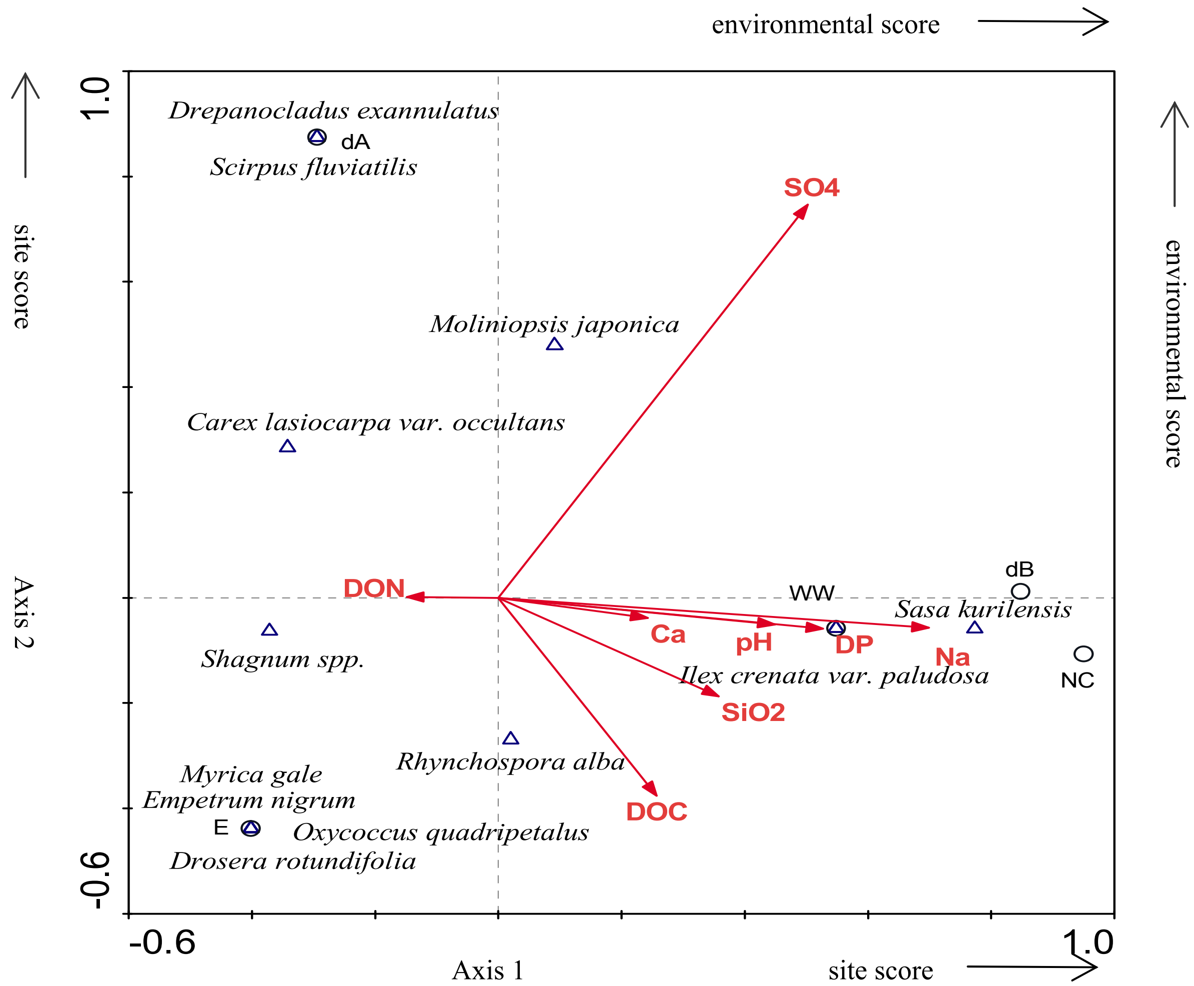

Fig. 1. Canonical correspondence analysis ordination of each species in sites with environmental variables represented by arrows along the site score and environmental score, respectively.

Many authors have shown that hydrologic parameters control the chemical and biotic processes in wetland ecosystems, and may be the most important process regulating wetland functions and development. Decomposition of peat soil due to lowered water level will affect the surface and pore water chemistry, particularly after leaching when this decomposed soil is washed by rainwater, yielded a high concentration of DOC. The decline of water level in the mire will also make the inflow from surrounding areas become possible. This inflow can be transporting soil and sediment that contain high concentrations of mineral, and cause changes in water chemistry. This process will also alter the plant communities of the mire, from nutrient-poor adapted plants to minerotrophic vegetations. The restoration of water chemistry along with the restoration of hydrological regime as a whole will have better effects in re-establishing the mire vegetation.

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