

## Limnological aspect of mires: background and a case study

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### INTRODUCTION

During the last two decades, wetlands have increasingly been attracting people's attention for conservation. The Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitats was first adopted in Ramsar, Iran, in 1971 [1-3]. By the fourth conference held in Kushiro City, Japan, in 1993, 76 countries joined the convention as contracting parties. The definition of wetlands given by the Ramsar Convention may be the most broad in sense including "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters" [2].

Wetlands, however, are least familiar ecosystems for limnologists except for marshes or lake littoral zones. Even from students of ecology classes, only a few pages are spared for wetlands in the general textbooks. Under these circumstances, wetland scientists began to organize international networks during 1980s and have held important scientific meetings. In addition, several books both general and academic and scientific journals were published or launched. Now we can access the information on wetlands much easier than before.

Among the various forms of wetlands, mires provide unique landscapes. Mires are peat-accumulating ecosystems (so they are also referred to as peatlands) and primarily classified into two categories according to their hydrology: "bogs" having no distinct inflows and "fens" receiving drainages from surrounding mineral soil [4, 5]. Although water is the major component in peat soil of mires, information is poor on the hydrology in many mires especially on its seasonal change and water budget.

In the present paper, we reviewed the status of mires or peatlands in Japan and showed our results of the investigation of mires especially from the viewpoint of limnology as well as biodiversity.

### STATUS OF THE MIRES IN JAPAN

#### *How much area of peatlands has been lost?*

The Japanese archipelago is located in the southern end of the world wide distribution of boreal peatlands [4, 6]. We have an accurate estimate of areas of peatlands and extant mires in northernmost Hokkaido Island, the second largest island in Japan, the area of which amounts to 22% of that of national lands. Hokkaido National Agricultural Experiment Station had accomplished a drilling survey in this island to a depth of 3 m at every horizontal grid point of 550 m by 270 m. Thus the area of peatlands was estimated as 200,642 ha there [7].

It was possible to make such an estimation only because the island had been preserved until the mass colonization of people starting in the last century. According to Sakaguchi [7], 62% of the original peatland in Hokkaido Island has been modified by agricultural development and urbanization, i.e., the area of existent mire is ca. 76,000 ha. As for the other islands, people colonized much earlier and most lowlands had been changed to paddies. Therefore we have not the accurate estimate of the peatland areas in these islands.

### *Inventorying mires*

The Environment Agency of the Prime Minister's Office has made a survey on vegetation in Japan in 1978 and 1984-1986. Wetland vegetations were listed up as *Vaccinium-Sphagnum* (cranberry--sphagnum moss) vegetation, *Molinopsis* and *Phragmites* (reed) vegetations [8]. Since geological information was not included in the survey, these vegetation areas did not correspond with peatland areas. In 1993, the Environment Agency conducted a survey on wetlands (mire, spring, marsh, lake, mangrove, paddy, etc.) larger than 1 ha in area. The results will be published next year. However about 70% of the nation's land area is mountainous areas covered with forests and grasslands, it is difficult to list up all the mires in these areas even in the latest survey.

### *Mire protection*

Several categories exist for the legal protection of mires: 1) National park (administered by the Environment Agency) and 2) Quasi-national park (administered by the prefectural governments under the supervision of the Environment Agency). Mires and its adjacent areas are designated as these parks, e.g., Kushiro Mire, Ozegahara Mire, Sarobetsu Mire. These parks are, however, not "nature reserves" since the term "park" means that the area should be used for recreation. 3) Prefectural natural parks (designated for preservation by the prefectural governments). 4) Natural monuments and special natural monuments (designated for preservation by Agency for Cultural Affairs, Ministry of Education): some mires, e.g., Ozegahara Mire, Kiritappu Mire and Akaiyachi Mire are designated as special natural monuments for nature protection districts. This may be the category of the highest level of protection in Japan.

To date, many mires have been designated as above categories of natural parks or monuments, yet a considerable number of mires are out of legal protection. Further, even for the protected mires, surrounding buffer zones are often excluded from the protected areas. For example, Kushiro Mire has a vast unprotected shedding area that is mainly used for rangeland.

### *Wetlands as Ramsar sites*

So far nine Ramsar sites have been designated in Japan. Of them only two sites are mires, i.e., Kushiro Mire and Kiritappu Mire and all others are ponds, river mouths and paddies that are the so-called wetlands defined by the Ramsar Convention. Nearly hundred wetlands are listed by a Japanese NGO, International Waterfowl and Wetlands Research Bureau (IWRB) Japan Committee, as candidates for Ramsar sites [9]. Yet a few of these sites are mires being distributed in Hokkaido Island. Again, the majority of the wetlands as important habitats for waterfowls are shallow lakes and ponds, rivermouths and coastal areas in Japan.

### *Education*

Mires in Japan are not so important as habitats for waterfowls. As stated before, Ozegahara Mire (760 ha) has been designated both as a national park and as a special natural monument. It is a complex of bogs and fens. More than ten thousand people visit there per day during the high season of tourism. The peak of the tourism coincides with the blooming of a kind of a skunk cabbage, *Lysichiton camtschaticense*, along the streams, which has been a symbolic plant for this mire. Many package tours are designed to visit there to march on the wood walks looking for the white flower. A great number of color guidebooks on this mire are available but only a few pages are spared for *Sphagnum* mosses. It is urgently necessary to appeal the role of *Sphagnum* mosses in a bog ecosystem and the importance of their conservation.

The lack of textbooks on mires or wetlands is also true in Japan. "Geology of Peatlands" (Sakaguchi, 1974 [10]) is a comprehensive textbook on peatlands but has long been out of print.

## LIMNOLOGICAL STUDIES ON MIRES

### *Mire pools*

Scientific research teams had been organized during 1950-1952 and 1978-1980 for the study of Ozegahara Mire. Shallow pools have been well studied in this mire from the viewpoint of typology [11-15]. Characteristic distribution of aquatic plants and invertebrates have been demonstrated in relations to water chemistry [12, 15]. In these studies, observations were made at most four times during the snow-free season. Yet more frequent studies are necessary to elucidate their productivity and the functioning of pool ecosystems.

Since the plants and animals are protected in mires (Ozegahara Mire is strictly protected as natural monument and national park), we have to develop methods for the estimation of biomass and abundance without disturbing thier habitats.

### *Groundwater and hydrology*

The classical work by Hogetsu et al. [16] in Ozegahara Mire illustrates clearly the vegetation change from *Molinopsis japonica* to sedge (*Carex Middendorffii*) and finally to buck bean (*Menyanthes trifoliata*) vegetations with elevating groundwater table. However, the range of water tables for these species to be distributed was wide enough to overlap each other. Tolerance to root inundation under anoxic conditions differs among the plant species, which plays a deterministic role of mire vegetation [17, 18].

A 30-cm seasonal change in groundwater table has been reported for raised bogs Königsmoor [19] and Laaviosuo [20]. Rainfall events raise the water table by more than 10 cm [20]. The seasonal change and the rainfall-induced fluctuation in Groundwater tables are larger for fen part than for bog part in Sarobetsu, Ishikari, Kushiro and Bibai Mires [21, 22]. Therefore care must be taken to interpret the relationship between vegetation and groundwater table based on a single observation. Damman and Dowhan (1980 [23]) measured the fluctuation in groundwater table for 2 months and obtained cumulative time against groundwater table, i.e., percentage of time the level was below the water table. On the basis of on this observation, they used an index, "50% groundwater level", for the analysis of bog plant distribution in relation to soil water content.

The change in seasonal fluctuation in water table and movement of water within

mires are clarified in a limited number of mires [21]. Such hydrological information is poor especially in bog ecosystems in Japan.

## CASE STUDY IN MIYATOKO MIRE

### *Study site*

We studied the ecosystem of a small mire, Miyatoko Mire, in central Honshu Island. The mire is located on a ridge at about 850 m a.s.l. and has an area of 8 ha with watershed area of 48.1 ha. The mire is covered with *Sphagnum fuscum*, *S. magellanicum*, *S. palustre* and *S. papillosum* and pools with *Menyanthes trifoliata*, *Nymphaea tetragona* and partly with *Phragmites australis*. Three streams originating from springs at the foot of the mountain flow through the mire. The pH value ranged between 5.6-6.7 seasonally at the spring sites, 4.9-6.8 in streams and ponds. The mire is a complex of bog and fen. Topographically lower parts are fens receiving stream flow [24].

### *Groundwater and hydrology*

Investigation wells were made along the slopes for monitoring of the groundwater table. Three wells with different depths of 0.5 m, 1.5 m and 2.5 m were set at five locations along a longitudinal slope, and 11 1-m-deep wells were arranged along another slope. Water table and chemical parameters were observed biweekly or monthly as well as several locations in open waters.

Concentrations of  $\text{NH}_4\text{-N}$  and  $\text{SiO}_2$  in groundwater increased with depth in peat soil, corresponding with a longer retention time of groundwater at a greater depth. Higher  $\text{SiO}_2$  concentration and lower  $\text{NH}_4\text{-N}$  and Mg concentrations were observed for the water in a pool located near the margin of the mire as compared to those in the upstream spring water. These facts indicated that the groundwater that might have originated from precipitation and has been retained only for a short period in surface soil leaked into the pool water [25].

### *Biodiversity in a mire ecosystem*

Fauna and flora were studied for streams and pools. A total of 105 species of algae mainly diatoms and desmids were recorded from two pool sites [26]. Although most of the species were common to each other site, dominant species differed greatly in terms of biomass. In the pool receiving the spring stream almost directly, diatoms were exclusively dominant with 90%-98% of total algal biomass while in the pond receiving a stream water flow throughout the *Sphagnum* mire, biomass of desmids were high as well as diatoms.

Benthic macroinvertebrate communities were dominated by an insect family Chironomidae. A total of 38 species of chironomid adults were collected by rearing larvae collected from various parts of mire waters and with a light trap and an insect net. These species belonged to four subfamilies, i.e., 13 Tanypodinae, one Prodiamesinae, nine Orthocladiinae and 15 Chironominae species [27]. The chironomid composition was similar to that of bog waters rather than fen waters since the number of species were higher for Tanypodinae than for Orthocladiinae, which was reported for Canadian mire waters [28]. Six to 11 species of chironomids were collected from each sampling site in Miyatoko Mire.

From a viewpoint of biodiversity, a fen ecosystem may provide a diverse habitat

for aquatic organisms even in this small mire. Little has been known so far of such kinds of small aquatic organisms.

As for terrestrial vegetation, 54 higher plants, i.e., seven *Sphagnum* species and 47 vascular plants have been recorded from the mire whereas more than 100 species of higher plants were recorded from the surrounding forests [29]. We cannot simply make a comparison in terms of number of species for the evaluation of biodiversity of mire terrestrial flora. Instead, we must pay attention for the species characteristic to mires and count the number of species of them.

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