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# Vegetation of water basins in the northern part of the Korean Peninsula

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ABSTRACT: Newly described are plant communities of water basins dominated by *Azolla pinnata* (*Lemno paucicostatae-Azollaetum pinnatae* ass. nova) and *Eichhornia crassipes* (*Lemna paucicostata-Eichhornia crassipes* community) as well as a group of communities in which *Nelumbo nucifera* predominates. In the latter group four clear-cut communities were distinguished: *Bidenti tripartitae-Nelumbetum nuciferae* ass. nova, *Ceratophyllo demersi-Nelumbetum nuciferae* ass. nova, *Monochorio plantagineae-Nelumbetum nuciferae* ass. nova, and *Myriophyllo spicati-Nelumbetum nuciferae* ass. nova. Phytosociological system of water basins communities of East Asia is presented.

KEYWORDS: vegetation, water basins, phytocoenology, Korean Peninsula

## Introduction

The vegetation of the northern part of the Korean Peninsula has been very little known. During the expeditions into North Korea in the years 1984, 1986, 1988 and 1990, attention was paid first of all to the phytocoenological research of the terrestrial communities (e.g. DOSTÁLEK et al. 1988, KOLBEK et al. 1989, DOSTÁLEK, KOLBEK et JAROLÍMEK 1990, ŠRŮTEK et KOLBEK 1992, 1994).

This is perhaps the first contribution concerning the vegetation of water basins in the northern part of the Korean Peninsula. In comparison with the territory of Central Europe, the water basins in North Korea are very rare, and are built first of all in the environs of greater towns. Water basins were mainly built for ornamental purposes in parks and rarely as sedimentation basins in surroundings of towns.

Rather numerous, however, are the plant communities of river banks (JAROLÍMEK, KOLBEK et DOSTÁLEK 1991) and rice fields (KOLBEK, DOSTÁLEK et JAROLÍMEK, submitted). This paper presents phytocoenological material from three localities situated near the towns in this region.

## Methods

The phytosociological relevés were collected in June, September and October 1986 and 1988 in optimally developed stands of aquatic vegetation in accordance with the principles of the Zürich-Montpellier school (BRAUN-BLANQUET 1964). Three types of layers (Ee-emerged plants, Ef-floating plants and Es-submerged plants) were distinguished in the stands. The relevés were taken in the surroundings of the towns of Pyongyang, Anju and Wonsan at altitudes from 10 to 50 m above sea level (Fig. 1).

The climatic data of studied localities are shown in the climatic diagrams from the towns of Pyongyang and Wonsan (Fig. 1). Water acidity was measured by the universal indicator paper. The nomenclature of species follows RI et HOANG (1984) except for *Azolla pinnata* R. Br.

The phytocenological material from North Korea was compared with communities described from Japan and South Korea. On the basis of the above mentioned material from this region, some of the described communities were recognized as associations.

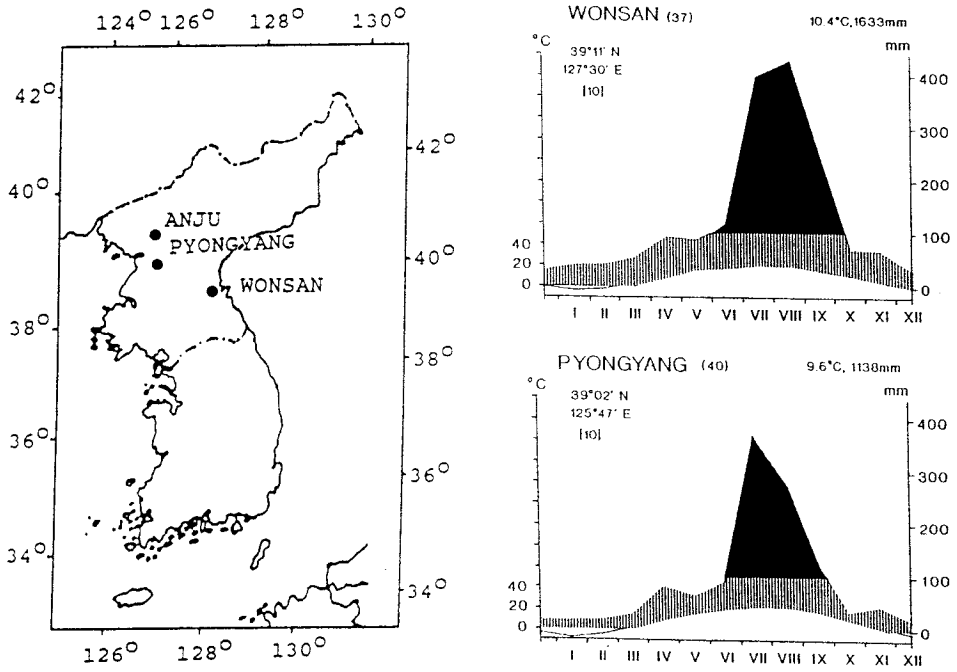


**Fig. 1. - Localities under study with climatic data taken from the nearest meteorological stations (according to KREBS 1984).**

## Plant communities

### 1 Communities dominated by *Azolla pinnata*

#### 1.1 *Lemno paucicostatae-Azollaetum pinnatae* ass. nova hoc loco

Table 1, relevé 1-4; nomenclatural type: relevé 1

Community dominated by *Azolla pinnata*. In 1986, *Azolla pinnata* was found and determined as a new species in the flora of North Korea (DOSTÁLEK, KOLBEK et JAROLÍMEK 1989). A community with this dominant species was found both in 1988 and 1990 only in Pyongyang in a number of water basins in the southwestern part of the town. The community achieved a cover of 80-100 % and was very poor in species (maximum 3 species per relevé). It was observed in eutrophic waters with a pH value of 6.1 and with a muddy sediment. *Azolla pinnata* occurred with a high cover also in the *Ceratophyllo demersi-Nelumbetum nuciferae* (see Table 2).

In the Japanese town of Kawasaki, MIYAWAKI et al. (1981) described an association poor in species identified as *Lemno paucicostatae-Salvinietum natantis* MIYAWAKI et TÜXEN 1960 in which *Lemna paucicostata, Spirodela polyrhiza* and *Salvinia natans* were the dominant species. Similar units were found by MIYAWAKI (1982, 1983, 1984, 1985, 1986, 1987) on the islands of Kanto, Kinki, Chubu, Chugoku, Tohoku and Shikoku. On Cheju island (South Korea), SONG (1991) recorded 2 relevés of the community *Lemna paucicostata-Spirodela polyrhiza*. No similar communities were found in North Korea, however individual species of these communities occur sparsely in the stands in its territory.

### 2 Communities dominated by *Eichhornia crassipes*

#### 2.1 *Lemna paucicostata-Eichhornia crassipes* community

Table 1, relevés 5-8

Community dominated by *Eichhornia crassipes* occurred with a high cover degree in strongly eutrophized water with pH 6.0 in the basins of Pyongyang. The plants grew up to 1 m above the water surface. This species is used as a food for pigs. A few individuals are replanted every year in the spring in the basins, since the local climatic conditions do not allow the plants to survive the winter in the open air. The favourable temperature during the vegetation period and plenty of nutrients enable their expansive growth and a high production of biomass in the eutrophic basins. The species thus forms stands with an extensive management.

Reported from the Kyushu island (Japan, MIYAWAKI 1981) was a community dominated by *Eichhornia crassipes*, which includes species occurring in stands of North Korea - e.g. *Ceratophyllum demersum, Lemna paucicostata, Spirodela polyrhiza* and *Hydrilla verticillata*.

**Table 1.** ***Lemno paucicostatae-Azollaetum pinnatae*** **ass. nova (relevé 1-4) and** ***Lemna paucicostata-Eichhornia crassipes*** **community (relevé 5-8).**

| Relevé No. | 1 | 2 | 3 | 4 | | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Area ($m^2$) | 1 | 1 | 1 | 1 | | 20 | 20 | 20 | 20 | |
| Cover (%) of | | | | | | | | | | |
| Ef (floating plants) | 95 | 80 | 95 | 100 | | 85 | 100 | 100 | 100 | |
| Es (submerged plants) | 2 | 2 | 0 | 0 | C | 1 | 0 | 0 | 0 | C |
| Deep of water (cm) | 70 | 70 | 70 | 70 | (%) | 60 | 60 | 65 | 65 | (%) |
| Height of stands (cm) | 1 | 1 | 1 | 1 | | 3 | 70 | 55 | 100 | |
| Ef - floating plants | | | | | | | | | | |
| *Azolla pinnata* | 5 | 5 | 5 | 5 | 100 | . | . | . | . | 0 |
| *Eichhornia crassipes* | . | . | . | . | 0 | 4 | 5 | 5 | 5 | 100 |
| *Lemna paucicostata* | r | + | + | . | 75 | 2 | + | 1 | . | 75 |
| *Spirodela polyrhiza* | . | . | . | . | 0 | + | + | . | . | 50 |
| Es - submerged plants | | | | | | | | | | |
| *Ceratophyllum demersum* | + | + | . | . | 50 | + | . | . | . | 25 |
| *Potamogeton crispus* | + | . | . | . | 25 | . | . | . | . | 0 |
| *Hydrilla verticillata* | . | . | . | . | 0 | + | . | . | . | 25 |

## 3 Communities dominated by *Nelumbo nucifera*

This group includes several communities, the common character of which is in most cases the occurrence of the dominant species *Nelumbo nucifera* with a characteristic physiognomy of the stand. Thanks to this conspicuous species, some stands form an emerged plant layer 50-180(300) cm height. *Nelumbo nucifera* is purposely propagated and exploited as a source of edible seeds.

### 3.1 *Ceratophyllo demersi-Nelumbetum nuciferae* ass. nova hoc loco

Table 2, relevé 1-7; nomenclatural type: relevé 7

Community dominated by *Azolla pinnata, Ceratophyllum demersum* and *Nelumbo nucifera* was observed during 1984-1990 in the southwestern part of Pyongyang in eutrophic basins with a muddy sediment. pH values of water fluctuated around 6.1. The water temperature was rather high; when measured on September 7, 1986, it was still 25 °C. The physiognomy of the whole stand above the water surface is formed by *Nelumbo nucifera*. The water surface is dominated by *Azolla pinnata, Ceratophyllum demersum* and the floating leaves of *Nelumbo nucifera*. The water column from the sediment to the surface is densely grown through by *Ceratophyllum demersum*. This stand makes the movement of fish impossible. The total cover is very high. The community is poor in species, because the dense stand of dominant species prevents the other ones from penetrating it.

Another analogous unit, *Ceratophyllum demersum-Najas marina*, was described by MIYAWAKI (1981) on Kyushu island.

**Table 2.** ***Ceratophyllo demersi-Nelumbetum nuciferae*** **ass. nova (relevé 1-7) and** ***Myriophyllo spicati-Nelumbetum nuciferae*** **ass. nova (relevé 8-13).**

| Relevé No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($m^2$) | 9 | 25 | 9 | 9 | 12 | 12 | 25 | | 16 | 9 | 10 | 10 | 12 | 12 | |
| Cover (%) of | | | | | | | | | | | | | | | |
| Ee (emerged plants) | 20 | 100 | 40 | 45 | 10 | 0 | 95 | | 0 | 0 | 0 | 0 | 0 | 0 | |
| Ef (floating plants) | 80 | 95 | 95 | 90 | 100 | 100 | 100 | C | 60 | 75 | 50 | 40 | 60 | 50 | C |
| Es (submerged plants) | 90 | 100 | 95 | 95 | 95 | 90 | 100 | (%) | 80 | 20 | 90 | 70 | 70 | 80 | (%) |
| Deep of water (cm) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | | 100 | 70 | 100 | 100 | 70 | 70 | |
| Height of stands (cm) | 80 | 90 | 100 | 110 | 100 | 50 | 130 | | 40 | 40 | 30 | 30 | 30 | 50 | |
| Ee - emerged plants | | | | | | | | | | | | | | | |
| *Nelumbo nucifera* | 2 | 5 | 3 | 3 | 2 | . | 5 | 86 | . | . | . | . | . | . | 0 |
| Ef - floating plants | | | | | | | | | | | | | | | |
| *Azolla pinnata* | 4 | 2 | 4 | 4 | 5 | 5 | 1 | 100 | . | . | . | . | . | . | 0 |
| *Ceratophyllum demersum* | 3 | 3 | 2 | 2 | 1 | + | 5 | 100 | . | . | . | . | . | . | 0 |
| *Nelumbo nucifera* | . | 3 | 2 | 2 | 1 | 1 | 2 | 86 | 4 | 4 | 3 | 3 | 2 | 3 | 100 |
| *Trapa pseudoincisa* | . | . | . | . | . | . | . | 0 | . | 1 | 2 | 1 | 2 | . | 57 |
| *Spirodela polyrhiza* | . | + | . | . | 1 | + | + | 57 | . | . | . | . | + | + | 33 |
| *Eichhornia crassipes* | + | + | . | . | . | . | . | 29 | . | . | . | . | . | . | 0 |
| *Potamogeton natans* | . | . | . | . | . | . | . | 0 | . | . | . | + | + | . | 33 |
| *Phragmites communis* | . | . | . | . | . | . | . | 0 | . | 2 | . | . | . | 2 | 33 |
| *Alisma orientale* | . | . | . | . | . | . | . | 0 | . | + | . | . | . | . | 17 |
| *Acorus calamus* | . | . | . | . | . | . | . | 0 | . | . | . | . | 2 | . | 17 |
| *Potamogeton pussillus* | . | . | . | . | . | . | . | 0 | . | . | . | . | . | 1 | 17 |
| Es - submerged plants | | | | | | | | | | | | | | | |
| *Ceratophyllum demersum* | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 100 | . | . | 1 | + | 2 | 3 | 67 |
| *Myriophyllum spicatum* | . | . | . | . | . | . | . | 0 | 5 | 2 | 5 | 4 | 3 | 3 | 100 |
| *Potamogeton crispus* | + | . | . | . | . | . | . | 14 | . | . | . | + | + | . | 33 |
| *Urticularia* sp. | . | . | . | . | . | . | . | 0 | . | . | . | . | + | 1 | 33 |
| *Hydrilla verticillata* | . | . | . | 1 | . | . | . | 14 | . | . | . | . | . | . | 0 |

### 3.2 Myriophyllo spicati-Nelumbetum nuciferae ass. nova hoc loco

Table 2, relevé 8-13; nomenclatural type: relevé 11

Community dominated by *Myriophyllum spicatum, Trapa pseudoincisa* and *Nelumbo nucifera* was found only in the surroundings of the town of Wonsan in the basins situated in the vicinity of the Sea of Japan. It occurred in relatively clean water, probably poorer in nutrients, with a sandy sediment and greater depths (up to 100 cm). *Nelumbo nucifera* represented the majority of floating plants. As a codominant, *Trapa pseudoincisa* asserted itself among the floating plants. In the submersed layer, *Myriophyllum spicatum* was the dominant species. These stands were the richest in species among all the communities observed there.

**Table 3. Communities dominated by *Nelumbo nucifera* and other hydrophilous species (relevé 1, 2), *Monochorio plantagineae-Nelumbetum nuciferae* ass. nova (relevé 3-9), and *Bidenti tripartitae-Nelumbetum nuciferae* ass. nova (relevé 10-15).**

| Relevé No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | 10 | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area ($m^2$) | 30 | 20 | 30 | 30 | 30 | 30 | 20 | 25 | 20 | | 25 | 25 | 12 | 25 | 25 | 25 | |
| Cover (%) of | | | | | | | | | | | | | | | | | |
| Ee (emerged plants) | 90 | 20 | 20 | 20 | 0 | 75 | 60 | 70 | 90 | C | 75 | 90 | 80 | 80 | <5 | 85 | C |
| Ef (floating plants) | 1 | 95 | 20 | 60 | 50 | 50 | 95 | 40 | 60 | (%) | 50 | 20 | 20 | 30 | 95 | 20 | (%) |
| Deep of water (cm) | 65 | 60 | 10 | 15 | 20 | 10 | 20 | 15 | 20 | | 30 | 20 | 20 | 10 | 10 | 20 | |
| Height of stands (cm) | 150 | 40 | 50 | 50 | 30 | 150 | 150 | 150 | 150 | | 150 | 300 | 220 | 170 | 180 | 300 | |
| Ee - emerged plants | | | | | | | | | | | | | | | | | |
| *Nelumbo nucifera* | 5 | 2 | 2 | 2 | . | 4 | 4 | 4 | 5 | 86 | 4 | 5 | 5 | 5 | 1 | 5 | 100 |
| Ef -floating plants | | | | | | | | | | | | | | | | | |
| *Nelumbo nucifera* | . | 3 | . | . | 2 | . | . | . | . | 14 | 3 | . | . | . | . | . | 17 |
| Other dominant species | | | | | | | | | | | | | | | | | |
| *Lemna paucicostata* | + | 3 | . | . | . | . | . | . | . | 0 | . | . | . | . | . | . | 0 |
| *Eichhornia crassipes* | . | 3 | . | . | . | . | . | . | . | 0 | . | . | . | . | . | . | 0 |
| *Potamogeton distinctus* | . | . | 1 | 4 | 2 | . | . | . | . | 43 | . | . | . | . | . | . | 0 |
| *Monochoria* * *plantaginea* | . | . | 2 | 1 | 1 | 1 | 2 | . | . | 71 | . | . | . | . | . | . | 0 |
| *Sagittaria trifolia* | . | . | . | 2 | 2 | . | . | 1 | . | 43 | . | . | . | . | . | . | 0 |
| *Spirodela polyrhiza* | . | + | . | . | 1 | 3 | 5 | 3 | 4 | 71 | 2 | . | . | . | . | . | 17 |
| *Bidens tripartita* | . | . | . | . | . | . | . | . | . | 0 | 2 | 2 | 2 | 3 | 4 | + | 100 |
| *Echinochloa crusgalli* | . | . | . | . | . | . | . | . | . | 0 | 2 | + | 1 | 1 | 3 | + | 100 |
| *Phragmites communis* | . | . | . | . | . | . | . | . | . | 0 | . | . | . | . | + | 2 | 33 |
| Other species | | | | | | | | | | | | | | | | | |
| *Persicaria cochinchinensis* | . | . | . | . | . | . | . | . | + | 14 | . | + | . | + | . | . | 33 |
| *Cyperus glomeratus* | . | . | . | . | . | . | . | . | . | 0 | . | + | + | + | . | . | 50 |
| *Ludwigia prostrata* | . | . | . | . | . | . | . | . | . | 0 | . | + | + | . | . | . | 33 |
| *Eclipta prostrata* | . | . | . | . | . | . | . | . | . | 0 | . | . | + | . | 1 | . | 33 |
| *Salix* * *tortuosa* | . | . | . | . | . | . | . | . | . | 0 | . | . | . | 1 | r | . | 33 |

Species in one relevé only: *Alisma orientale* +: 5, *Persicaria thunbergii* +: 6, *Persicaria hydropiper* +: 13, *Digitaria ciliaris* 1: 14, *Pennisetum alopecuroides* 1: 14, *Pycreus polystacyus* +: 14, *Themeda japonica* +: 14, *Erigeron canadensis* r: 14.

Under the name of *Potamogeton crispus* community MIYAWAKI et al. (1973) described stands from the town of Kamakura which are very analogous to this unit. The relevés include *Potamogeton crispus, Nelumbo nucifera, Trapa japonica* and *Ceratophyllum demersum*. Related is also the community *Nymphaea tetragona-Trapa japonica* described by MIYAWAKI et FUJIWARA (1974) in the town of Itami, *Nymphoido indicae-Trapetum japonicae* MIYAWAKI et al. 1977, and *Trapa japonica* community from Japan (MIYAWAKI 1984-1987). Other analogous unit, *Potamogeton oxyphyllum-Myriophyllum spicatum*, was describes by MIYAWAKI (1981) on Kyushu island.

**3.3 *Monochorio plantagineae-Nelumbetum nuciferae* ass. nova hoc loco**
Table 3, relevé 3-9; nomenclatural type: relevé 5

**3.4 *Bidenti tripartitae-Nelumbetum nuciferae* ass. nova hoc loco**
Table 3, relevé 10-15; nomenclatural type: relevé 11

The table of relevés includes four groups of communities occurring in the basins with various depths of water and with different characters. Relevés 1 and 2 in Table 3 and relevés from the foregoing communities (Tables 1 and 2) come from the basins with a higher water level. The other relevés in Table 3 represent successionally advanced units of shallow water. They come from sedimentation basins used as sewage clarifying ponds which have a low water level and a thick mud layer. In dependence on the character of the locality and the supply of diaspores, some species given in the table become predominant. Interesting is the occurrence of *Monochoria vaginalis* var. *plantaginea*, whose optimum of occurrence in the Korean Peninsula and Japan can be observed rather in the communities of rice fields in recent years (MIYAWAKI 1960, SONG 1991, KOLBEK, DOSTÁLEK et JAROLÍMEK submitted). Whereas relevés 3-9 from Anju represent the stands of a sedimentation pond from an earlier succession stage (pH value of water 6.3), relevés 10-15 from Pyongyang exemplify a basin, whose successionally older stands are already transitional to the communities of banks of the alliance *Panico-Bidention frondosae* MIYAWAKI et OHBA 1972 (JAROLÍMEK, KOLBEK et DOSTÁLEK 1991).

## Conclusion

Only rare data on the vegetation of water basins can be found in the available botanical literature from the Korean Peninsula (SONG 1991). Most of the comparable sources come from Japan (MIYAWAKI 1960, 1981-1987, MIYAWAKI et FUJIWARA 1974, MIYAWAKI et al. 1981). On the basis of comparison of known literature from Japan, South Korea and our phytosociological data from North Korea it is possible to construct following system:

*Lemnetea* DE BOLÓS et MASCLANS 1955
*Lemnetalia minoris* DE BOLÓS et MASCLANS 1955
*Lemnion paucicostatae* MIYAWAKI et J. TX. 1960
*Azollaetum japonicae* MIYAWAKI et al. 1983
*Lemno paucicostatae-Azollaetum pinnatae* ass. nova
*Lemno paucicostatae-Salvinietum natantis* MIYAWAKI et J. TX. 1960
*Pistio-Azollaetum imbricatae* MIYAWAKI et J. TX. 1960
*Spirodeletum oligorhizae* OKUDA 1978
*Lemna gibba* community (MIYAWAKI 1983)
*Lemna paucicostata-Azolla imbricata* community (MIYAWAKI 1982, 1983)
*Lemna paucicostata-Spirodela polyrrhiza* community (MIYAWAKI 1981-1985, SONG 1991)
*Lemna valdiviana* community (MIYAWAKI 1983)
*Wolffia arrhiza-Lemna paucicostata* community (MIYAWAKI 1984)

Communities analogous to eurosiberian *Hydrocharitetalia* RÜBEL 1933
*Hydrocharition* RÜBEL 1933
*Eichhornia crassipes* community (MIYAWAKI 1981)
*Lemna paucicostata-Eichhornia crassipes* community KOLBEK et DOSTÁLEK
*Potametea* KLIKA in KLIKA et NOVÁK 1941
*Potametalia* KOCH 1926
*Nymphaeion albae* OBERD. 1957
*Myriophyllo spicati-Nelumbetum nuciferae* ass. nova
*Nymphoido indicae-Trapetum japonicae* MIYAWAKI et al. 1977
*Nymphaea tetragona-Trapa japonica* community (MIYAWAKI et FUJIWARA 1974)
*Trapa japonica* community (MIYAWAKI 1984)
*Potamion pectinati* (KOCH 1926) GÖRS 1977
*Hydrilla verticillata* community (MIYAWAKI et al. 1981, MIYAWAKI et FUJIWARA 1974)
*Hydrilla verticillata-Myriophyllum verticilatum* community (MIYAWAKI 1982)
*Najas marina-Ceratophyllum demersum* community (MIYAWAKI 1981)
*Potamogeton crispus* community (MIYAWAKI et al. 1973)
*Potamogeton oxyphyllus* community (MIYAWAKI 1984)
*Potamogeton oxyphyllus-Myriophyllum spicatum* community (MIYAWAKI 1981)

Communities analogous to eurosiberian *Phragmitio-Magnocaricetea* KLIKA in KLIKA et NOVÁK 1941
*Oenanthetalia aquaticae* HEJNÝ in KOPECKÝ et HEJNÝ 1965
*Oenanthion aquaticae* HEJNÝ ex NEUHÄUSL 1959
*Bidenti tripartitae-Nelumbetum nuciferae* ass. nova
*Ceratophyllo demersi-Nelumbetum nuciferae* ass. nova
*Monochorio plantagineae-Nelumbetum nuciferae* ass. nova

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## Appendix 1

### Location of relevés

Table 1: rel. 1-4, Pyongyang, ponds in the park near the river Potonggang, 20/10/1986; 5-8, Pyongyang, ponds near the hotel Potonggang, about 50 m from the left bank of the river Potonggang, 07/09/1986.

Table 2: rel. 1-7, Pyongyang, ponds near the hotel Potonggang, about 50 m from the left bank of the river Potonggang, 07/09/1986; 8-13, Wonsan, ponds about 4 km NW of the town in the vicinity of the Sea of Japan, 09/06/1988.

Table 3: rel. 1-2, Pyongyang, ponds near the hotel Potonggang, about 50 m from the left bank of the river Potonggang, 07/09/1986; 3-9, Anju, ponds and clarifying basins, 26/09/1986; 10-15, Pyongyang, sedimentation basin on the NW border of the town, 28/09/1986.

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