Journal of Plant Biology, December 1999, 42(4) : 287-293

Plant Community Structure in Reclaimed Lands on the West Coast of Korea

Byeong Mee Min[1]* and Joon-Ho Kim[2]
[1]Department of Science Education, Dankook University, Seoul 140-714, Korea
[2]Department of Biology, Seoul University, Seoul 151-742, Korea

To clarify the vegetation structure of salty areas, species distribution was survayed according to topography, species association, community ordination, and community classification. We studied one natural tidal flat and five reclaimed lands on the western coast of Korea. Species composition and vegetation profiles changed conspicuously over time and by topographical regions. Regardless of the time that elapsed after reclamation, halophytes and glycophytes coexisted on the sites where the leaching of soil salts was slow. Species association was weak among plants in the early stages on reclaimed lands. With time, however, the strength of species associations increased among halophytes and glycophytes, and the two groups were linked by salt-tolerant glycophytes. This resulted in a series of species associations on old reclaimed lands. In the study of plant community ordination, halophytic communities were located on one side of axis I, glycophytic communities on the other. Several communities of salt-tolerant glycophytes were located between the two groups. When key species were used to classify communities, we found that halophytic and glycophytic communities were intermixed.

Keywords: Classification, Halophytes, Ordination, Reclaimed land, Species association, Vegetation profile

The vegetation on marine salt marshes is found in zones along an environmental gradient. The main factors that determine zonation are (1) the tide, or inundation period by seawater (Clark and Hannon, 1969); (2) soil moisture and salt content (Mall, 1969); and (3) interactions among plants, e.g., competition (Jefferies, 1972).

Because the tide is cut off and soil salts are leached by freshwater or rainfall after reclamation, soil on reclaimed land is transformed over time into land soil (as defined by soil salt content), even if salt levels are high in the early stages (Min and Kim, 1997a, 1997b). However, because plants that grow on reclaimed lands and salt marshes vary in their salt tolerance, according to species (Waisel, 1972; Min and Kim, 1983; Ihm, 1987), the pattern of reclaimed land vegetation follows along soil properties.

Studies on saltmarsh vegetation began in the early twentieth century (Ganong, 1903; Flowers, 1934; Chapman, 1977). Especially, Chapman (1975) classified the halophytic communities of the world into 15 groups; the saltmarsh vegetation of Korea was included in the Sino-Japanese group. Early studies of reclaimed land vegetation were carried out by analyzing plant associations (Conrad, 1935), but since the 1960s, the phytosociological methods of Braun-Blanquet (1964) have been applied (Umezu, 1964; Beeftink and Gehu, 1973). Gray and Bunce (1972) and Marrel (1979) analyzed vegetation-distribution data using a computer program. Despite the broad range of reclaimed land in Korea, studies of vegetation structure are few. In the present study, we clarified the structure of vegetation communities on these reclaimed lands.

STUDY AREA AND METHODS

The study areas and their periods of time since reclamation were described previously (Min and Kim, 1999). We selected one natural tidal flat (Namdong) and five reclaimed lands (total of six research stations) that varied in the amount of time that had elapsed since reclamation: Hyundai A (1 year), Hyundai B (2 years), Jangdeog (8 years), Mado (12 years), and Baegseog (30 years). Field surveys were carried out from August to September of 1984. In 1999, the Namdong station was converted into a residential quarter, Hyundai A and B areas into rice paddies, and the Baegseog area into a garbage dump. The Mado area had remained under natural vegetation.

We had four objectives in this field survey: to (1) diagram vegetation profiles along topographical lines (considering altitude especially), (2) analyze species association, (3) ordinate communities, and (4) classify

*Corresponding author; fax +82-2-796-2857
e-mail bmeemin@hanmail.net

communities.

The vegetation profiles were diagrammed in reference to topography and relative horizontal distance. At each of the six stations, the dominant species were mapped and identified by unique symbols. At Namdong, the vegetation chosen for mapping was located at the furthest distance from the mean high tide mark (MHTM), in a band 4 m wide. At Hyundai A, Hyundai B, Jangdeog, and Baegseog, vegetation was diagrammed from the dam to the MHTM that had existed before reclamation. At Mado, mapping followed the topographical features only, because the altitude of the dam was similar to the pre-reclamation MHTM, and was the result of a creek bank.

For analyzing species associations, 300 ~ 350 samples were chosen from 25 x 25 cm quadrats at each station. The location of a quadrat was defined as the place where two species grew adjacent to each other; the overlapping species were identified as belonging in each quadrat.

To ordinate and classify communities of dominant species, stands >5 m in diameter were selected in which vegetation and microenvironment were homogeneous. In each stand, 10 samples were chosen from the 25×25 cm quadrats. In each quadrat, vegetative coverage was checked for each species. The aboveground portions of the sample plants were then cut and sorted according to species. Fresh weights were measured and subsamples were prepared for determining dry weights in the lab. These subsamples were then dried at 80°C for 48 h. The mean dry weight of each species, per stand, was estimated from the dried subsample weights.

Vegetation structure was determined from species association and community ordinations and classifications. A two by two contingency table was framed (according to Greig-Smith, 1983), and χ^2 values were tested at significance levels of 1%, 5%, and 10%. If each cell value in a contingency table was below 5, and <10 samples were gathered for a particular species from all quadrats, those data were omitted from the analysis. The importance value for each species was calculated from mean values of dry weight and coverage. Community ordination was then analyzed using the calculated importance value and a detrended correspondence analysis program (DCA; Hill, 1979a). Communities were classified according to presence or absence of each species. The importance value of each species was degraded using a two-way indicator species analysis program (TWINSPAN; Hill, 1979b).

RESULTS AND DISCUSSION

Species Distribution and Topography

The species distribution according to topography at our six stations is shown in Figure 1. At Namdong, *Suaeda japonica* formed a sparse population on the broad intertidal flat, with a mean height of 20 cm. Below the MHTM, *S. japonica*, *Carex scabrifolia*, *Zoysia sinica*, *Phragmites communis*, *Salicornia herbacea*, and *Triglochin maritimum* formed small patches. In this lower area, *Z. sinica*, *T. maritimum*, and *C. scabrifolia* were fully inundated by seawater at high tide, the other species only partly. On the upper part, above the MHTM, *Artemisia scoparia*, *Aster tripolium*, and *Limonium tetragonum* were found. In the transition between tidal flat and dry land, *Lathyrus japonica*, *Suaeda asparagoides*, *Erigeron canadensis*, and *Setaria viridis* grew in a mixed community. The former two species are halophytes, the latter two are glycophytes. In the area in which the altitude was >80 cm from the MHTM, only glycophytes grew.

At the Hyundai A station (1 year), *S. japonica*, 30~ to 60 cm tall, was distributed continuously in about a 2-km range between land (MHTM before reclamation) and the dam. No brackish water was found in this region. In areas that were 10 m wide between the MTHM and the dam, *P. communis*, *C. scabrifolia*, and *Z. sinica* formed patches 4~ to 6 m wide.

At Hyundai B station (2 years), a very broad area of *S. asparagoides* grew, 1 m long and with high biomass. *S. herbacea*, *Chenopodium virgatum*, *A. tripolium*, *Atriplex subcordata*, *Suaeda asparagoides*, and *L. tetragonum* were distributed near the MHTM. In some areas, *P. communis*, *C. scabrifolia*, *Z. sinica*, *Calamagrostis epigeios*, and *A. scoparia* formed patches 4~ to 5 m wide. *Carex pumila*, *Salsola komarovi*, *Typha angustata*, and *Chenopodium glaucum* grew in sand dunes or creeks.

At Jangdeog (8 years), the dam was filled with brackish water. In the lower regions, we found *S. japonica*, *A. tripolium*, *S. herbacea*, *Z. sinica*, and *C. scabrifolia*. *P. communis*, *Sonchus brachyotus*, *Echinochloa crus-galli*, *A. scoparia*, and *Imperata cylindrica* var. *koenigii* grew in the middle regions and on sloped sites. At the higher sites, *S. viridis*, *C. epigeios*, *L. tetragonum*, *P. communis*, *T. angustata*, *I. cylindrica* var. *koenigii*, and *Aeschynomene indica* were found. Glycophytes populated the highest site.

At the Mado station (12 years), *P. communis* and *Scirpus fluviatilis* grew in creeks or on sloped and hol-

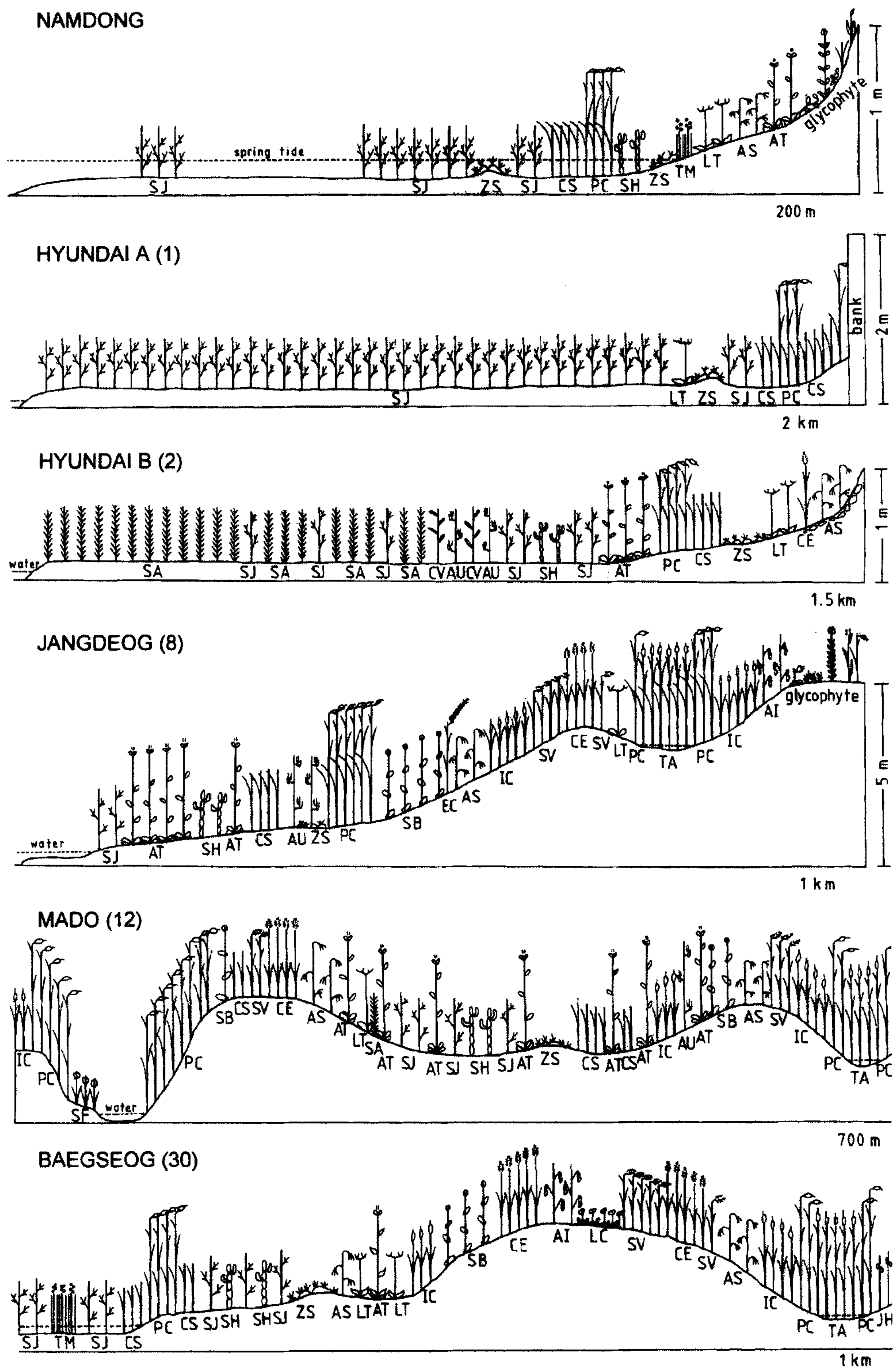

Figure 1. Vegetation profiles and topography at the six study stations. AI, *Aeschynomene indica*; AS, *Artemisia scoparia*; AT, *Aster tripolium*; AU, *Atriplex subcordata*; CE, *Calamagrostis epigeios*; CS, *Carex scabrifolia*; CV, *Chenopodium virgatum*; EC, *Echinochloa crus-galli*; IC, *Imperata cylindrica* var. *koenigii*; JH, *Juncus haenkei*; LC, *Lotus corniculatus* var. *japonicus*; LT, *Limonium tetragonum*; PC, *Phragmites communis*; SA, *Suaeda asparagoides*; SB, *Sonchus brachyotus*; SF, *Scirpus fluviatilis*; SH, *Salicornia herbacea*; SJ, *Suaeda japonica*; SV, *Setaria viridis*; TA, *Typha angustata*; TM, *Triglochin maritimum*; ZS, *Zoysia sinica*.

low sites. *S. herbacea, S. japonica, S. asparagoides, A. tripolium, L. tetragonum, I. cylindrica* var. *koenigii, Z. sinica,* and *C. scabrifolia* were found in lower regions where the surface was flat and drainage was poor. *A. scoparia* and *A. subcordata* grew on higher sites, and *C. epigeios, S. viridis, S. brachyotus,* and *C. scabrifolia* were found at the highest sites.

At Baegseog (30 years), the soil salt content was greatest in the lowest area where seawater had flowed, but almost all of the salt had leached out in the highest areas. On inundated sites, *S. japonica, T. maritimum, C. scabrifolia,* and *S. herbacea* formed pure or mixed communities. *P. communis, Juncus haenkei,* and *T. angustata* were found on the sides of a ditch into which fresh water flowed. *Z. sinica, L. tetragonum, A. scoparia, A. tripolium,* and *I. cylindrica* var. *koenigii* grew on the flat, mid- altitude site, where drainage was good. *C. epigeios, S. brachyotus, A.* indica, *Lotus corniculatus* var. *japonicus,* and *S. viridis* were found on the highest site. In addition, *Scirpus triqueter, Polygonum aviculare, Trifolium repens, Bromus japonicus, Pennisetum alopecuroides,* and *Plantago major* var. *japonica* grew irregularly.

Species Association

Species associations (Fig. 2) were based on surveys of plant communities at four stations: Hyundai B (2 years), Jangdeog (8 years), Mado (12 years), and Baegseog (30 years). At Hyundai B, *A. tripolium* was associated positively with *P. communis,* at the 10% significance level. No other species associations were found at this station.

At Jangdeog, several species associations were found. The first was *S. japonica-S. herbacea-A. tripolium-Z. sinica,* all halophytic species that grew in high salt areas. This association was significant at the 5% level. The second grouping was *S. brachyotus-S. viridis,* two salt-tolerant glycophytic species found in low salt areas (Min and Kim, 1999). This association also was significant at the 5% level. In addition, two group associations of *C. scabrifolia* and *C. epigeios* had 10% significance levels.

At Mado, the following species associations were grouped: (1) *A. tripolium-S. herbacea-S. japonica-S. asparagoides,* at the 1% significance level; *A. tripolium-L. tetagonum,* at the 5% significance level; *S. herbacea-A. scoparia,* at the 10% significance level; and (2) *S. viridis-S. brachyotus,* at the 1% significance level; *S. brachyotus-I. cylindrica* var. *koenigii-Z. sinica-C. epigeios,* at the 5% significance level. The former group comprised halophytic species, whereas the latter was made up of salt-tolerant, glycophytic species.

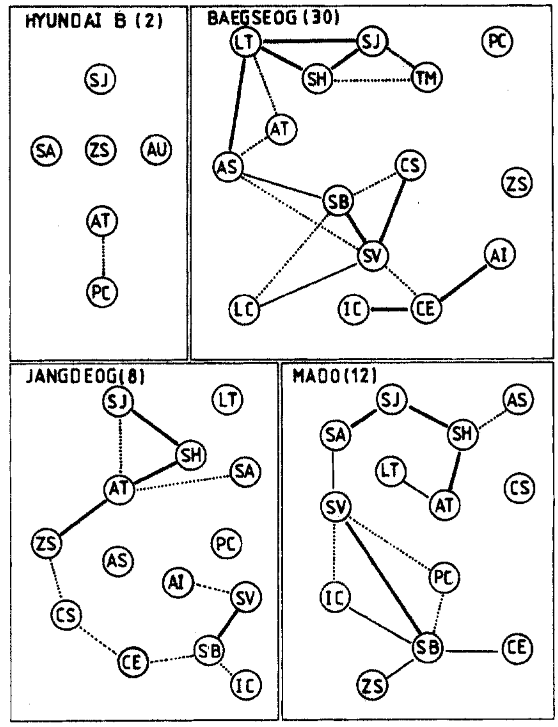

Figure 2. Positive species association between plants at Hyundai B, Jangdeog, Mado, and Baegseog, based on the χ^2 values. Abbreviations of species are defined in Figure 1. ——, $p \leq 1\%$; ——, $1\% \leq p \leq 5\%$; ········, $5\% \leq p \leq 10\%$.

The former group was related to the latter via *S. asparagoides* and *S. viridis,* which were associated at the 5% significance level. Therefore, most species were associated with each other and formed an association series.

At Baegseog, three species associations were grouped according to their mechanisma for salt-tolerance (Waisel, 1972): (1) obligatory halophytes, composed of *S. herbacea-S. japonica-L. tetragonum-A. tripolium*. These species were associated with each other at the 5% significance level; (2) facultative halophytes or salt-tolerant glycophytes, composed of *S. brachyotus-S. viridis-C. scabrifolia;* and (3) glycophytes, composed of *I. cylindrica* var. *koenigii-C. epigeios-A. indica*. Species associations appeared among the three groups. For example, *A. scoparia* in the first group was associated with *S. brachyotus* in the second group, at the 5% significance level. *S. viridis* from the second group was associated with *C. epigeios* from the third group, at the 10% significance level. Most species were associated with each other and formed an association series as at the Mado station.

Early associations were weak when species were integrated according to the time elapsed since reclamation. The longer the time period, the greater the association. In the late stage after reclamation, species associations were found in one of three groups: obligatory halophytes, facultative halophytes, and glycophytes. By then, almost all species were associated with each other and had formed a series.

Community Ordination

The DCA ordination program was used to analyze community data from Hyundai B (14 communities), Jangdeog (14 communities), Mado (14 communities), and Baegseog (19 communities). The results are shown in Figure 3.

The rate of the total eigenvalue for axis I and axis II was over 80%, and the grouping degree of plant communities could be predicted by their arrangements along these axes. Plant community distributions at four of the stations did not make up a group on axis I, and were considered a series. At Hyundai B, the axis I showed *T. maritimum, S. herbacea, P. communis, C. scabrifolia,* and *A. tripolium* communities on the left side, and *C. pumila* and *C. virgatum* communities on the right. This demonstrated that the communities were not divided between halophytic and glycophytic species groups; communities from the two groups were intermixed. Based on these results, the existing halophytes and newly intruding glycophytes probably coexisted because of rapid salt leaching over the two-year period since reclamation.

For the stations at Jangdeog, Mado, and Baegseog, the halophytic species communities of *S. japonica, S. asparagoides, S. herbacea, A. tripolium,* and *Limonium tetragonum* were found on one side of the axis, with the glycophytic species communities of *A. indica, C. epigeios,* and *I. cylindrica* var. *koenigii* on the other side. Especially at Baegseog, where reclamation had taken place 30 years previously, the obligatory halophyte communities of *S. japonica, S. herbacea,* and *T. maritimum* made up a conspicuously isolated group.

These results coincided with those of Min and Kim (1999), who showed that plant distribution on reclaimed lands depended on soil moisture amd salt content. Therefore, distribution or formation of plant communities on reclaimed land was probably not

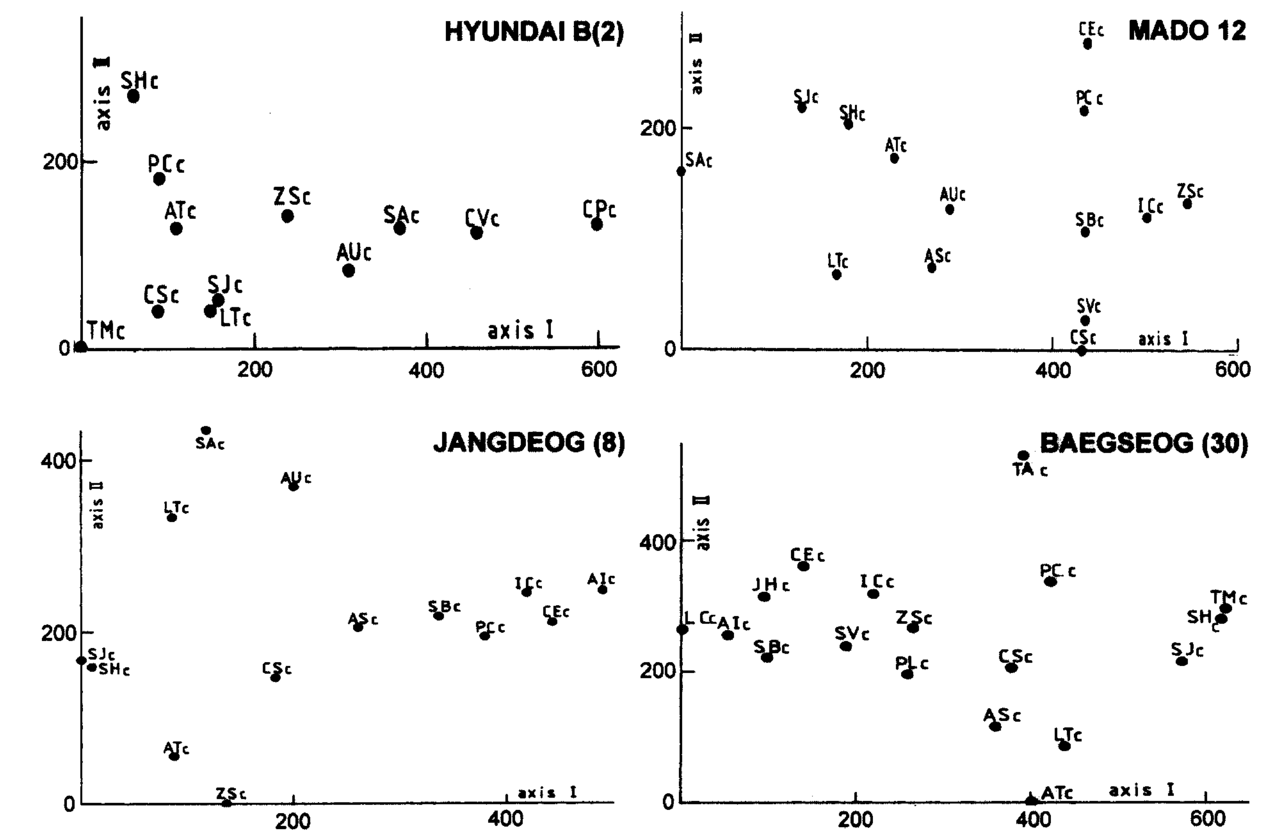

Figure 3. Ordination of stand by detrended correspondence analysis (DCA), based on similarity of species diversity and calculated by each percentage of phytomass and coverage. 'C' indicates plant community. Abbreviations of species are defined defined in Figure 1.

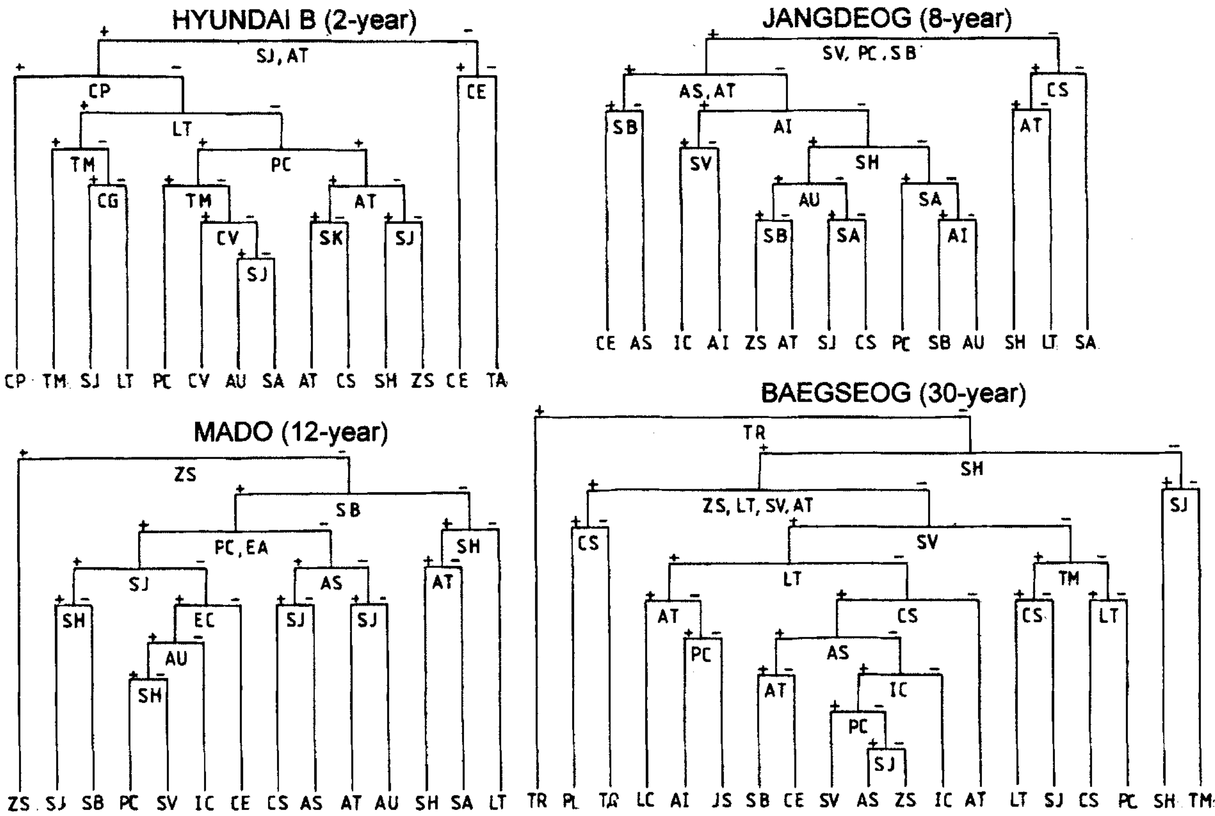

Figure 4. Dendrograms of divisive classification of stand by two-way indicator species analysis (TWINSPAN), based on similarity by presence or absence of species. Abbreviations of species are defined in Figure 1.

decided according to phytosociological properties but by the soil environment.

Community Classification

The results of community classification by the TWINSPAN program are shown in Figure 4. This method utilized qualitative data of species composition.

Classification levels for the stations at Hyundai B, Jangdeog, Mado, and Baegseog were 7, 6, 7, and 10, respectively. Classification level and key species within the same species community varied among stations, and the communities were not grouped into the halophyte and glycophyte categories. For example, the representative halophyte communities of *S. japonica, S. asparagoides, S. herbacea, T. maritimum,* and *L. tetragonum* were agglomerated at Level 5 for Hyundai B, Level 6 for Jangdeog and for Mado, and Level 9 for the Baegseog station. Although these species grew in high- salt areas (see Min and Kim, 1999), their communities were not related according to species composition. In contrast, the representative glycophyte communities of *C. epigeios, I. cylindrica* var. *koenigii, A. indica,* and *S. viridis* showed agglomerations at Level 7 for Hyundai B, Level 5 for Jangdeog, Level 3 for Mado, and Level 6 for Baegseog. In reference to species composition, halophytes and glycophytes coexisted in mixed communities, and the vegetation was diverse on the reclaimed lands.

Overall, species associations were defined as being in one of three groups: obligatory halophytes, facultative halophytes, and glycophytes. Almost all of the species were associated with each other and formed a series. However, when the community ordination and classification analysis programs were used, vegetation was not clearly grouped into halophytic and glycophytic communities. This was probably because the distribution or formation of plant communities on reclaimed land was not determined by phytosociological properties but by soil environment. In the early stages after reclamation, vegetation properties were more properly described via the species association method rather than by the community ordination or classification methods.

Received September 29, 1999; accepted November 18, 1999.

LITERATURE CITED

Beeftink WG, Gehu JM (1973) Spartinetea maritimae, *In* R Tuxen, ed, Prodrom des groupments vegetaux d'Europe, J Cramer, Lehre, pp 1-43

Braun-Blanquet J (1964) Pflanzensoziologie. Grundzuge der Vegetationskunde. Springer-Verlag, Vienna

Chapman VJ (1975) The salinity problem in general, its importance, and distribution with special reference to natural halophytes, *In* A Poljakoff-Mayber, J Gale, eds, Plants in Saline Environments, Springer-Verlag, New York, pp 7-24

Chapman VJ (1977) Wet Coastal Ecosystems. Elservier Scientific Publishing Company, New York

Clark LD, Hannon NJ (1969) The mangrove swamp and salt marsh communities of the Sydney district. II The holocenotic complex with particular reference to physiography. J Ecol 57: 213-234

Conrad HS (1935) The plant associations of central Long Island. Amer Midland Natur 16: 433-516

Flowers S (1934) Vegetation of the Great Salt Lake region. Bot Gaz 95: 353-418

Ganong WF (1903) The vegetation of the Bay of Fundy salt and dike marshes: an ecological study. Bot Gaz 36: 161-186

Gray AJ, Bunce RJH (1972) The ecology of Orecambe Bay. VI Soil and vegetation of the salt marshes - a multivariate approach. J Appl Ecol 9: 221-234

Greig-Smith P (1983) Quantitative Plant Ecology. 3rd ed. Blackwell Scientific, Oxford

Hill MO (1979a) DECORANA-a FORTRAN program for detrended correspondence analysis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca, New York

Hill MO (1979b) TWINSPAN-a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics, Cornell University, Ithaca, New York

Ihm B-S (1987) The distribution and growth of halophytes at the coastal marsh. Bull Inst Litt Biota 4: 71-80

Jefferies RL (1972) Aspects of salt-marsh ecology with particular reference to inorganic plant nutrition, *In* RSK Barnes, J Green, eds, The Estuarine Environment, Applied Science Publisher, London, pp 61-85

Mall RE (1969) Soil-water-salt relationships of waterfowl food plants in the Suisum marsh of California. California Dep Fish Game Wildl Bull 1: 1-59

Marrel EV (1979) Environmental management of coastal dunes in the Netherlands, *In* RC Jefferies, AJ Davy, eds, Ecological Processes in Coastal Environments, Blackwell Scientific, Oxford, London, pp 543-570

Min BM, Kim J-H (1983) Distribution and cyclings of nutrients in *Phragmites communis* communities of a coastal salt marsh. J Plant Biol (Korean J Bot) 26: 17-32

Min BM, Kim J-H (1997a) Soil texture and desalination after land reclamation on the West coast of Korea. Korean J Ecol 20: 133-143

Min BM, Kim J-H (1997b) Desalinization characteristics after reclamation of reclaimed lands on the Western coast of Korea. Korean J Ecol 20: 275-283

Min BM, Kim J-H (1999) Plant Distribution in Relation to Soil Properties of Reclaimed Lands on the West Coast of Korea. J Plant Biol 42: 279-286

Umezu Y (1964) Uber die Salzwasserpflanzengesellschaften in der Nahe von Nordkyushu. Japanese J Ecol 14: 153-160

Waisel Y (1972) Biology of Halophytes. Academic Press, New York