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Coastal Vegetation on the Western, Southern, and Eastern Coasts of South Korea

Byung-Sun Ihm[1]*, Jeom-Sook Lee[2], and Jong-Wook Kim[1]
[1]Department of Biology, Mokpo National University, Muan-Gun 534-729, Korea
[2]Department of Biology, Kunsan National University, Kunsan 573-701, Korea

We used the Braun-Blanquet method to study the vegetation of coastal wetlands in South Korea. Three habitat types were found, i.e., salt marshes, salt swamps, and sand dunes. These plant communities were classified as: 1) two groups (five associations each) in the salt marshes that comprised either annual herbaceous halophytes (Class *Thero-Salicornietea*), or biennial/perennial herbaceous species (Class *Asteretea tripolii*); 2) one group in the salt swamps consisting of five hydrophilous halo-tolerant associations (Class *Phragmitetea*); and 3) three groups in the sand dunes, including one association of annual herbaceous halophytes (Class *Salsoletea komarovii*), seven associations of herbaceous perennial halophytes (Class *Glehnietea littoralis*), and one association of shrub perennial halophytes (Class *Viticetea rotundifoliae*). These three habitat types accounted for the majority of the six main classifications of coastal vegetation distributed in South Korea.

Keywords: coastal vegetation, phytosociology, salt marsh, salt swamp, sand dune

Coastal wetlands comprise various habitat types, including salt marshes, salt swamps, and sand dunes. Classifying their communities by vegetation type may be based on nature conservation. Wetlands that are found in sheltered areas usually are supplied with sediments of either river or marine origin (Chapman, 1974; Jefferson, 1975). The sharp spatial boundaries among the various plant species follow environmental gradients (del Moral and Watson, 1978; Disraeli and Fonda, 1979; Armstrong et al., 1985; Upkong, 1991). Previous study results have suggested that external factors related to hydrology and salinity play a major role in determining the distribution pattern and abundance of wetland plants within and across coastal wetland types (Hong, 1956; Hong et al., 1970; Chapman, 1974; Beeftink, 1975; de Jong and Drake, 1981; Ustin et al., 1982; Kolbek and Dostálek, 1996).

In South Korea, the coastal communities are among the most poorly understood vegetation units, although research has been conducted on the physiognomic, floristic, and ecophysiological characteristics of halophytic species (Kim, 1971, 1975; Kim et al., 1982; Kim and Song, 1983, 1985; Oh and Ihm, 1983; Min, 1985; Munica and Dostálek, 1985; Lee, 1989; Kolbek and Dostálek, 1996; Ihm and Lee, 1998; Min and Kim, 1999a, 1999b). Likewise, Kim and Ihm (1988) and Jung and Kim (1998) have used phytosociological approaches to investigate these coastal wetlands.

The objective of the current study was to clarify the synecological and syntaxonomical characteristics of coastal wetland vegetation in South Korea.

*Corresponding author; fax +82-61-454-0267
e-mail ihmbs@chungkye.mokpo.ac.kr

MATERIALS AND METHODS

Study Area

Three coastal areas in South Korea were investigated: 1) the western coast at Okku, Iksan, Kochang, Yongkwang, Hampyung, Muan, Shinan, and Yongam; 2) the southern coast at Haenam, Changhung, Bosung, Sunchon, and Masan; and 3) the eastern coast at Youngduk, Pohang, Wolsung, Pusan, and Yangsan (Fig. 1). Coastal vegetation in these regions was monitored from September 1999 to August 2001. The soils belonged primarily to the saline series, and were categorized as entisols and inceptisols following the USA comprehensive system of soil classification (Soil Survey Staff, 1975).

Three distinct habitat types -- salt marsh, salt swamp, and sand dune -- were described according to their hydrology, soil texture, etc. (Ihm and Lee, 1998). Salt marshes generally are characterized by higher salinity and clay content. Salt swamps have

Figure 1. Map showing surveyed area (▨) on the western, southern, and eastern coasts of South Korea.

moderate salinity and clay content, but higher soil moisture content, and occur in areas either with high-water tables or where fresh water flows down into salt marshes. Sand dunes have both lower salinity and soil moisture content.

Vegetation Analysis

Sample relevés were performed according to the method of Braun-Blanquet (1964), and included the dominance and sociability of all vascular plant species. To analyze for particular plant associations, we prepared 2 × 2 contingency tables for recording the presence or absence of each species. Correlations were analyzed in 426 of the quadrats, and χ^2 values were calculated for occurrence of the remaining species. Only positive associations were used in species classifications; plant communities were determined by the classification method and by tabular comparison (Mueller-Dombois and Ellenberg, 1974). To distinguish coastal vegetation units, the classified communities were compared with those of other regions (Waisel, 1972; Beeftink, 1977; Miyawaki et al., 1983). Taxonomic nomenclature followed that of Lee (1993); names of syntaxa corresponded with the codes for phytosociological nomenclature (Barkman et al., 1986).

RESULTS AND DISCUSSION

Using association analysis and χ^2 values, we diagrammed the species constellation shown in Figure 2. Three main groups of plant species were recognized among the coastal habitat types of salt marsh, salt swamp, and sand dune. The majority of the species were included in this distribution of vegetation. The salt-marsh species group included the association of *Artemisia scoparia*, *Aster tripolium*, *Atriplex gmelini*, *Limonium tetragonum*, *Salicornia herbacea*, *Suaeda asparagoides*, *Suaeda maritima*, *Suaedetum japonicae*, and *Zoysia sinica*. Those species in the salt-swamp group were an association of *Carex scabrifolia*, *Phragmites communis*, *Scirpus fluviatilis*, and *Triglochin maritima*. The sand-dune species association included *Calystegia soldanella*, *Carex kobomugi*, *Carex pumila*, *Elymus mollis*, *Imperata cylindrica* var. *koenigii*, *Ischaemum anthephoroides*, *Ixeris repens*, *Lathyrus japonica*, *Lysimachia mauritiana*, *Salsola komarovi*, and *Vitex rotundifolia*.

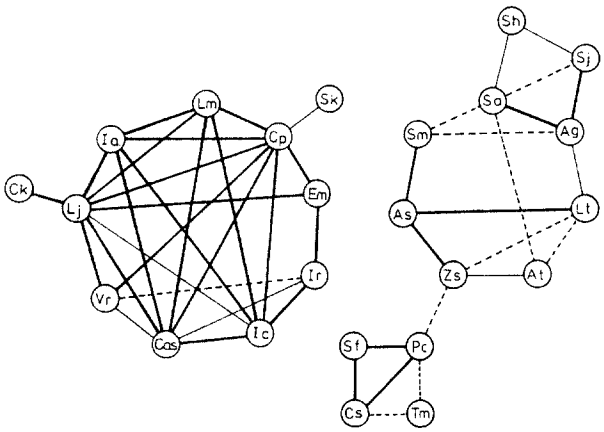

Figure 2. Species constellation showing the positive relationship based on chi-square values in coastal vegetation. Thick, thin, and dotted lines are probability at <0.5%, 0.5 - 2.5%, and 2.5 - 5.0% levels, respectively. **Ck,** *Carex kobomugi*; **Lj,** *Lathyrus japonica*; **Ia,** *Ischaemum anthephoroides*; **Lm,** *Lysimachia mauritiana*; **Cp,** *Carex pumila*; **Sk,** *Salsola komarovi*; **Em,** *Elymus mollis*; **Ir,** *Ixeris repens*; **Ic,** *Imperata cylindrica* var. *koenigii*; **Cas,** *Calystegia soldanella*; **Vr,** *Vitex rotundifolia*; **Sh,** *Salicornia herbacea*; **Sj,** *Suaeda japonica*; **Sa,** *Suaeda asparagoides*; **Sm,** *Suaeda maritima*; **Ag,** *Atriplex gmelini*; **As,** *Artemisia scoparia*; **Lt,** *Limonium tetragonum*; **Zs,** *Zoysia sinica*; **At,** *Aster tripolium*; **Sf,** *Scirpus fluviatilis*; **Pc,** *Phragmites communis*; **Cs,** *Carex scabrifolia*; **Tm,** *Triglochin maritimum*.

Following the Braun-Blanquet methodology, we placed all associations into the following classes:

Class *Thero-Salicornietea*

The communities in the class *Thero-Salicornietea* were characterized by growth forms of annual herba-

Table 1. Syntaxonomical scheme of vegetation.

Thero-Salicornietea
  Thero-Salicornietalia
    Thero-Salicornion
      Salicornietum herbaceae
    Thero-Suaedion
      Suaedetum japonicae
      Atriplici-Suaedetum maritimae
      Suaeda asparagoides community
      Suaeda maritima community

Asteretea tripolii
  Zoysietalia sinica
    Zoysion sinica
      Zoysietum sinicae
      Artemisietum scopariae
      Limonietum tetragoni
      Aster tripolium community
      Atriplex gmelini community

Phragmitetea
  Phragmitetalia
    Phragmition
      Triglochietum maritimae
      Caricetum scabrifoliae
      Phaceluretum latifolii
      Phragmites communis community
      Scirpus fluviatilis community

Salsoletea komarovii
  Salsoletalia komarovii
    Salsolion komarovii
      Salsola komarovi community

Glehnietea littoralis
  Glehnietalia littoralis
    Carcion pumilae
      Caricetum pumilae
      Messershmidia sibirica community
      Lysimachia mauritiana community
      Ishaemum anthephoroides community
      Elymus mollis community
      Carex kobomugi community
      Ixeris repens community

Viticetea rotundifoliae
  Viticetalia rotundifoliae
    Ischaemo-Viticion rotundifoliae
      Imperato cylindricae-Viticetum rotundifoliae

ceous halophytes on the mud flats of salt marshes, estuaries, and reclaimed areas. Our results were in agreement with the classification proposed by Ohba et al. (1973), Chapman (1974), Miyawaki et al. (1983), Ellenberg (1986), Kim and Ihm (1988), and Asri and Ghorbanli (1997). Table 1 presents the association belonging to this class, i.e., the *Atriplici-Suaedetum maritimae* community, *Salicornietum herbaceae*, the *S. asparagoides* community, the *S. maritima* community, and *S. japonicae*.

Class *Asteretea tripolii*

The class *A. tripolii* (Table 1) included herbaceous perennial halophytes growing on dry salty and sandy flats. Our observations agreed with the classification proposed by Ohba et al. (1973), Beeftink (1977), and Miyawaki et al. (1983). The associations belonging to this class were the community of *A. tripolium*, *Artemisietum scopariae*, *Limonietum tetragoni*, and *Zoysietum sinicae*, as well as the *A. gmelini* community.

Class *Phragmitetea*

The communities in the class *Phragmitetea* (Table 1) were characterized by populations of hydrophilous plants found on the margins of salty and brackish swamps, streams, areas with high groundwater tables, and localities where fresh water flowed down into salt marshes. This vegetation type class was suggested by Ohba et al. (1973), Miyawaki et al. (1983), Ellenberg (1986), Kolbek and Dostálek (1996), and Asri and Ghorbanli (1997). The associations belonging to this class were *Caricetum scabrifoliae*, *Phaceluretum latifolii*, the *P. communis* community, the *S. fluviatilis* community, and *Triglochietum maritimae*.

Class *Salsoletea komarovii*

Communities characterized by annual herbaceous halophytes growing on sand dunes should be included in the class *S. komarovii*. This is in accordance with the scheme for salt-marsh vegetation in northeastern Asia, as proposed by Ohba et al. (1973) and Miyawaki et al. (1983). The one association in this class was the *S. komarovi* community (Table 1).

Class *Glehnietea littoralis*

The communities in class *G. littoralis* were characterized by herbaceous perennial halophytes that stabilized sand dunes through their production of rhizomes (Table 1). Each community comprised three to five species, in accordance with the scheme for northeast Asian salt-marsh vegetation that was proposed by Ohba et al. (1973), Miyawaki et al. (1983), Munica and Dostálek (1985), Kim (1986), Kim and Nam (1996), and Jung and Kim (1998). The associations belonging to this class were *Caricetum pumilae*, plus the individual communities of *C. kobomugi*, *E. mollis*, *Ishaemum anthephoroides*, *I. repens*, *L. mauritiana*, and *Messershmidia sibirica*.

Class *Viticetea rotundifoliae*

Kim and Ihm (1988) have described the class *V. rotundifoliae* for sand-dune shrub communities in South Korea. The single association belonging to this class was *Imperato cylindricae-Viticetum rotundifoliae* (Table 1). Our results supported the syntaxonomical schemes proposed by Ohba et al. (1973), Miyawaki et al. (1983), Kim and Ihm (1988), and Jung and Kim (1998).

Salt-marsh vegetation is generally characterized by its simplicity of structure and uniform species composition (Munica and Dostálek, 1985; Kolbek and Dostálek, 1996; Asri and Ghorbanli, 1997). Each of our associations had one or, sometimes, two dominants with or without associated species. The individual communities of *A. maritimae*, *S. herbaceae*, *S. asparagoides*, *S. matitima*, and *S. japonicae* were the important vegetation units in the early- successional stage. *S. herbaceae* occurred in circular or irregularly shaped patches on tidal mud flats. This association was very poor in species, and was often monodominant. Known as a pioneer on reclaimed land, this community is found in areas with low soil water potential (approximately −50 bars) and high light intensity (Kim, 1971; Chapman, 1974; Beeftink, 1975; Kim and Song, 1983; Ihm, 1989).

Associated species occurred in the margins of the salt marshes. The lower margin was dominated by *S. japonicae*, which were found in flat coastal areas where flow of seawater was slow. Their extensions varied greatly, from only a few square meters to several square kilometers. The upper margin was dominated by the communities of *A. scopariae*, *A. tripolium*, *A. gmelini*, *L. tetragoni*, and *Z. sinicae*. *Z. sinicae*, found in sandy soils, were associated with *S. japonica*, and *S. maritima* and *S. asparagoides* community. Although usually classified as a sand dune community (Miyawaki et al., 1983; Munica and Dostálek, 1985; Kolbek and Dostálek, 1996), the *Z. sinicae* were classified as a salt marsh community in this study because of their habitat and associated species.

Salt swamp habitats were located in estuaries or in salt marshes supplied by fresh water springs. Their dominant communities were *C. scabrifoliae*, *P. communis*, *S. fluviatilis*, and *T. maritimae*. The *P. communis* community grows mostly in fresh water, but may also be found in brackish and saline situations (Kim and Song, 1983; Oh and Ihm, 1983). Its associated species are *T. maritima, S. asparagoides,* and *Z. sinica*, which, in South Korea, are broadly distributed in the estuaries of the Nagdong (Kim et al., 1982), Seomjin (Oh and Ihm, 1983), and Youngsan rivers (Kim and Song, 1983). *T. maritimae* were found in circular-shaped patches in both fresh- and seawater. Plants were 20 to 60 cm tall, with coverage of 70 to 100%. Their associated species were *C. scabrifolia* and *P. communis*.

The sand dune region was dominated by the shrubby community of *I. cylindricae-V. rotundifoliae* and by perennial grass communities, such as *C. kobomugi*, *C. pumila*, *E. mollis*, *I. cylindrica* var. *koenigii*, *I. anthephoroides*, and *I. repens*. In addition, this habitat type included the herbaceous halophyte communities of *L. mauritiana* and *S. komarovi*. *I. cylindricae-V. rotundifoliae* was a typical evergreen shrub community found in coastal sand dunes, having long root systems that extended several meters. These communities occur extensively in the sand dunes of northeast Asia (Miyawaki, 1977; Lee et al., 1982; Miyawaki et al., 1983; Munica and Dostálek, 1985; Ihm, 1989; Jung and Kim, 1998; Min and Kim, 2000). Their associated species was *I. cylindrica* var. *koenigii*.

Because the habitat types described in this study were consistent with typical patterns of plant associations, we suggest that edaphic factors, periodic inundation, and saline water tables are the primary environmental influences that determine plant distribution. Similar results were found by Kim and Ihm (1988), Ihm (1989), Lee (1989), and Min and Kim (1999a, 1999b). Likewise, Ihm and Lee (1998) reported that edaphic factors related to hydrology and salinity also affected the distribution and abundance of wetland plants within and across coastal wetland types.

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