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Studies on Plant Succession of Sand Bars at the Nagdong River Estuary

II. Vegetation Development and Interspecific Associations

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洛東江 河口 砂洲 植生의 遷移에 관한 研究

II. 植生形成과 種間相關

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ABSTRACT

The processes of vegetation development and interspecific association were studied as a part of a successional study in the sand bars at the Nagdong River estuary in Korea. The major pioneer plant species in the sand bars were *Salsola komarovi*, *Carex pumila* and *Cynodon dactylon*. In embryonic sand bars, Namusitdeung and Galmaegideung, the processes of vegetation development after colonization by pioneer species were closely interdependent with the development of the sand dune. The vegetation types of embryonic sand bars were divided into two groups: sand dune plants, and annual and perennial forbs. Those of old sand bars, Baeghapdeung and Ogryudeung, were also divided into two groups: sand dune plants, and salt marsh plants. The results of interspecific association coincided well with the actual distribution of plant communities in the sand bars. The degree of vegetation development in each sand bar agreed with the order of successional stage observed in this study area.

INTRODUCTION

The processes of sand dune formation and vegetation development are interdependent. There are many reports on the processes of sand dune formation and colonization by plants, and different pioneer plant species have been reported in different localities (Nicholson, 1952; Gemmel *et al.*, 1953; Laing, 1954; Ishizuka, 1961; Chapman, 1964; Saito *et al.*, 1965; Hewettt, 1970; Ranwell, 1972). The main factors in colonization and subsequent

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growth of plant species on sand dunes are mobility of the dune itself and deficiency of available water and nutrients (Chapman, 1964).

The distribution of plant communities are influenced by slight differences in topography (Zedler and Zedler, 1969). Hierarchial association analysis was initiated by Goodall (1953) to examine the interrelationships of vegetation with its environment. Agnew(1961) made a species diagram of communities using an adaptation of the technique outlined by Goodall (1953).

This report is an attempt to clarify the process of sand dune vegetation development, and to construct an actual natural vegetation map in order to substantiate the results of interspecific association as a part of a successional study in the sand bars at the Nagdong River estuary.

METHODS

The study areas and sampling procedures were described in a previous paper (Mun and Kim, 1985). An actual natural vegetation map of each sand bar was constructed using the line transect method (Küchler, 1967). One hundred of (1×1)m-quadrats were sampled along the line transects on each sand bar in Namusitdeung and Galmaegideung, and 150 quadrats were sampled on each sand bar in Baeghapdeung and Ogryudeung. The presence or absence of each species was recorded in each quadrat and 2×2 contingency tables were made. Association analysis between plant species pair was carried out using the chi-square method(Agnew, 1961). The significance of chi-square values was judged at 1% and 5% levels. The positive or negative association between each species pair was used to construct a chi-square matrix. Only positive associations were used to construct the species diagram.

RESULTS

Process of vegetation development. Immediately after emergence above the water level, the sand bar has a low, smooth and simple surface(Fig. 1-A). As dune formation proceeds, the sand bar becomes divided into three parts(Fig. 1-B). The foreshore feeds sand to the dune area by beachcombers. The backshore is not influenced by direct wave action,

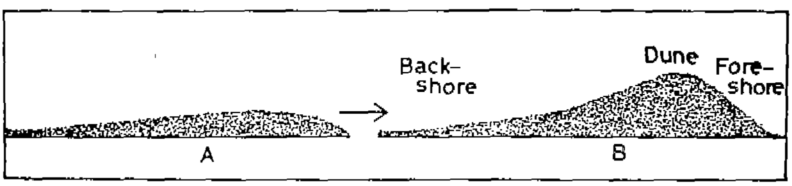

Fig. 1. Profiles showing a typical sand bar at the study area. A, initial stage; B, stage after dune formation finished.

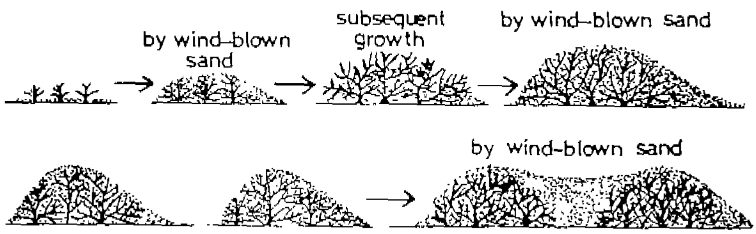

Fig. 2. Diagrammatic representation of the process of sand dune development at the study area.

and thus floating soil particles, mostly silt and clay, from the upper stream of the river precipitate in this area. It will develop into salt marsh in process of time.

The major pioneer plant species on the embryonic sand bars, Namusitdeung and Galmaegideung, were *Salsola komarovi*, *Carex pumila* and *Cynodon dactylon*. The formation of sand mounds by the colonization of *S. komarovi*, an annual plant, on bare sand bars is depicted in Fig. 2. As the plant grows after germination, the aerial parts impede the wind, the sand particles carried by wind being deposited around the plants and gradually burying them. As the sand accumulates, continued growth of the *S. komarovi* creates a generally higher mound than the surrounding area. These mounds are united to form a larger mound, and eventually a sand dune, during the growing season. Another process of sand dune formation occurs through the colonization of *C. dactylon*. It has many long stoloniferous rhizomes which reticulate the sand surface and prevent sand from blowing. Sometimes, the process of sand dune formation is geared up when *C. dactylon* invades sand mounds formed by *S. komarovi*, *C. pumila*, *Calystegia soldanella* and *Ixeris repens* also contribute to the fixation of sand dunes with long horizontal stolons.

The formation and destruction of dunes in embryonic sand bars take place repeatedly due to occasional windstorms. If a new sand bar begins to emerge a few hundred meters seaward from an existing sand bar, the latter becomes gradually stabilized due to the reduction of direct wave action. The more dune heightens and stabilizes, the more the salt spray is reduced and the leaching of salts from the soil increases. *Lathyrus japonica*, *Erigeron canadensis*, *Imperata cylindrica* var. *koenigii* and *Oenothera odorata* invade such desalted dunes. Consequently, they form mixed plant communities with the existing dune plants.

The backshores and dune slacks of Baeghapdeung and Ogryudeung were developed into salt marshes. The vegetation in these areas was quite different from that of sand dunes in both floristic composition and distribution patern. In the muddy salt marsh in Ogryudeung, small mounds covered with perennials such as *Zoysia sinica*, *Carex scabrifolia* and *Phragmites communis* were scattered. Their shapes were circular or elliptical, 1~10m in diameter and 10~40 cm in height. As the rhizomes of these plants extend, the mounds are gradually united and develop into a vast salt marsh vegetation. Unlike the dune vegetation, the plant communities of the salt marsh were distributed with distinct zonation.

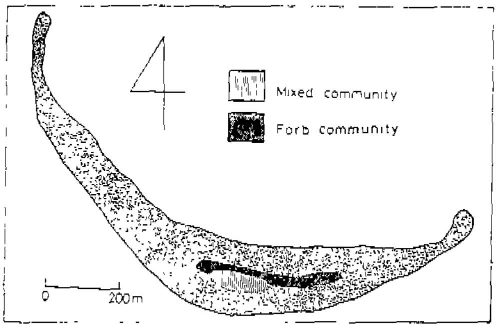

Fig. 3. Actual natural vegetation map of Namusitdeung.

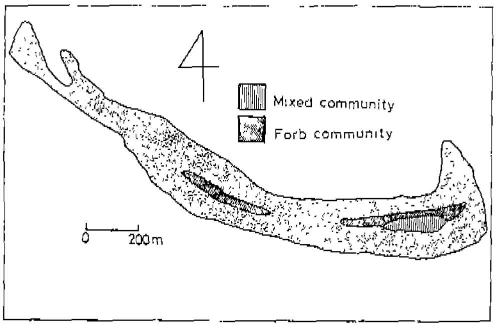

Fig. 4. Actual natural vegetation map of Galmaegideung.

Vegetation map. The actual natural vegetation maps of Namusitdeung and Galmaegideung are shown in Figs. 3 and 4. The vegetation was narrowly distributed in their central parts, and formed a mixed community mainly consisting of *C. pumila*, *C. dactylon* and *P. communis*. Annual or perennial forbs colonized the backshore-side of the mixed community. The actual natural vegetation maps of Baeghapdeung and Ogryudeung are more diversified (Figs. 5 and 6). The mixed communities developed on sand dunes were classified into several associations, such as *Cynodo-Caretum pumilae*, *Imperato-Lathyretum japonicae* and *Oenothero-Lathyretum japonicae* (Oosting, 1956; Chapman. 1964). Within the mixed community, several consociations such as *Imperetum cylindricae*, *Oenotheretum odoratae* and *Lathyretum japonicae* were identified. At the backshores and dune slacks, *Caretum scabrifolae* and *Phragmitetum communae* were developed. The *Hemarthro-Phragmitetum communae* association was developed in both Baeghapdeung and Ogryudeung. Especially, *Phragmitetum communae* occupied the most area of salt marsh in both Baeghap-

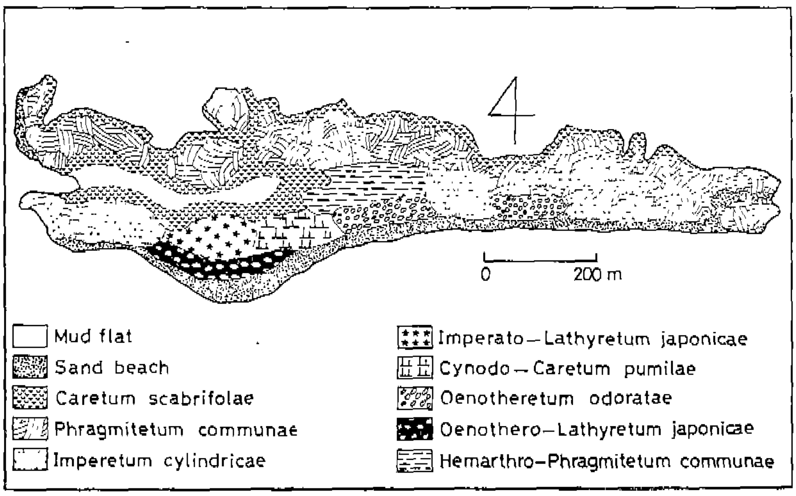

Fig. 5. Actual natural vegetation map of Baeghapdeung.

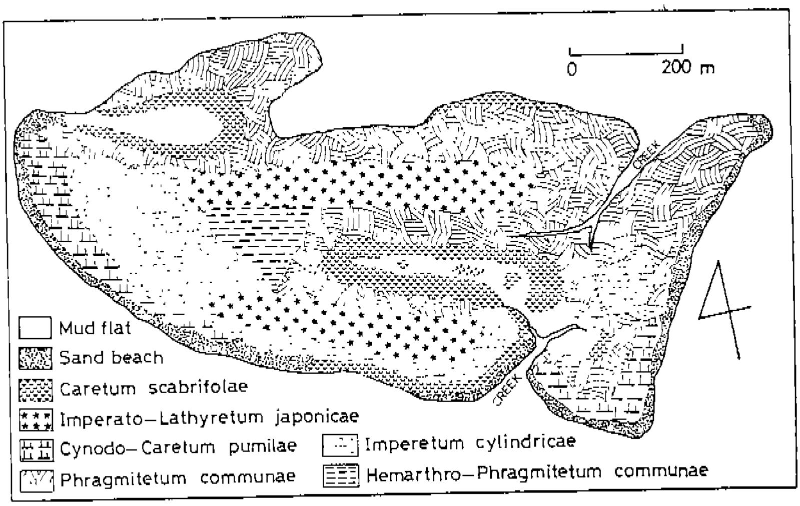

Fig. 6. Actual natural vegetation map of Ogryudeung.

++ (− −) : 1% level
+ (−) 5% level

Cynodon dactylon(Cd)										
Carex kobomugi(Ck)	+									
Calystegia soldanella(Cs)	++	+								
Ixeris repens(Ir)			+							
Carex pumila(Cp)	+	+		+						
Phragmites communis(Pc)	+	+			+					
Salsola komarovi(Sk)		−−			+					
Messerschmidia sibirica(Ms)			−			+	+			
Atriplex gmelini(Ag)		−−	−			−−	++	+		
Rumex crispus(Rc)			−			−−	+		+	
Beidens teipartita(Bt)			−			−		+	+	+

Fig. 7. Chi-square matrix showing the positive and negative species relations in Namusitdeung.

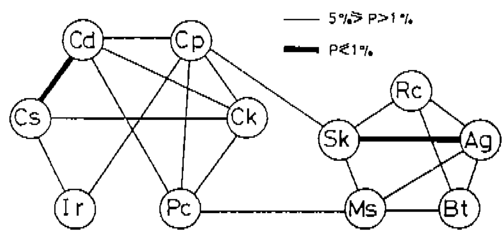

Fig. 8. Species diagram based on the chi-square value in Namusitdeung. Refer initial symbols to the plant names in Fig. 7.

++ (− −): 1% level
+ (−).5% level

Carex pumila(Cp)										
Carex kobomugi(Ck)	++									
Cynodon dactylon(Cd)	++	++								
Phragmites communis(Pc)	++	++								
Ixeris repens(Ir)	+	+								
Calystegia soldanella(Cs)	+	++	+		++					
Salsola komarovi(Sk)		−−	+			++				
Rumex crispus(Rc)		−−					+			
Atriplex gmelini(Ag)		−−				−−	++	++		
Suaeda maritima(Sm)						−	+	++	+	
Messerschmidia sibirica(Ms)								++	+	+

Fig. 9. Chi-square matrix showing the positive and negative species relations in Galmaegideung.

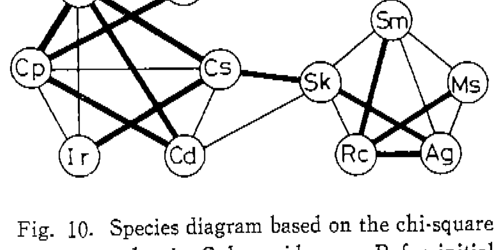

Fig. 10. Species diagram based on the chi-square value in Galmaegideung. Refer initial symbols to the plant names in Fig. 9.

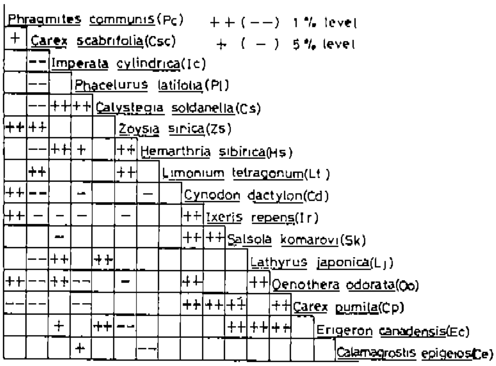

Fig. 11. Chi-square matrix showing the positive and negative species relations in Baeghapdeung.

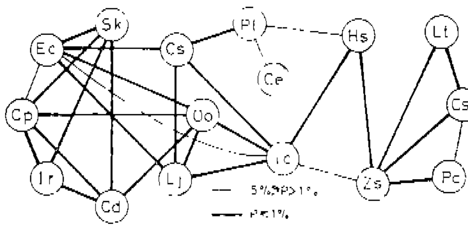

Fig. 12. Species diagram based on the chi-square value in Baeghapdeung. Refer initial symbols to the plant names in Fig. 11.

deung and Ogryudeung, having a great biomass.

Interspecific association. Among the plant species encountered in quadrats for each sand bar, 11 species in Namusitdeung and Galmaegideung, 16 species in Baeghapdeung, and 17 species in Ogryudeung occurred with 5% frequency or more. The chi-square matrix showing the positive or negative association among the species in Namusitdeung, Galmaegideung, Baeghapdeung and Ogryudeung are depicted in Figs. 7, 9, 11 and 13. The species diagrams based on the chi-square value for each sand bar are shown in Figs. 8, 10, 12 and 14. In both Namusitdeung and Galmaegideung, species diagrams are divided into two groups; one is composed of perennials such as *C. pumila*, *C. dactylon*, *C. soldanella* and *Carex kobomugi* which are growing on sand dune, the other is composed of mainly annual or perennial forbs such as *S. komarovi*, *Atriplex gmelini* and *Rumex crispus*. The species diagrams of Baeghapdeung and Ogryudeung are also divided into two groups; one is composed of sand dune plants with strong positive association and the other is composed of salt marsh plants with incomplete rings.

DISCUSSION

Several plant species such as *Agropyron juncetum*, *Ammophila arenaria*, *Elymus mollis* and *Elymus arenarius* are reported as pioneer species on bare sand bars (Nicholson, 1952; Gemmell *et al.*, 1953; Ishizuka, 1961; Hewett, 1970). In this study area, the annual plant *S. komarovi* is the pioneer species which contributes to the formation of sand dunes (Fig. 2). However, the sand dune formed by the *S. komarovi* may be vulnerable to wind, especially in winter, because of the death of the plant itself. The stability of sand dunes enhanced by invasion of *C. dactylon*, *C. pumila* and *C. soldanella*. They make a reticulate carpet on the dune surface with stoloniferous rhizomes, which prevent sand from blowing. Thereafter, the sand dune begins to form dense vegetation. It has been found that tillers of *C. dactylon* are prostrate in Namusitdeung and Galmaegideung where the plants grow

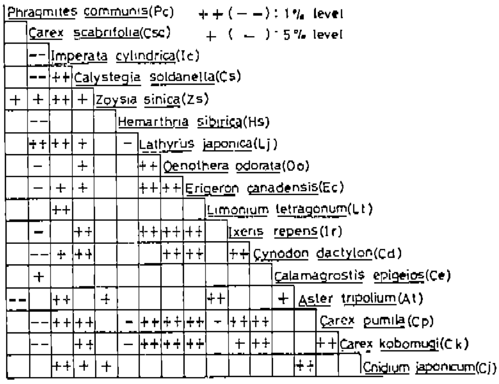

Fig. 13. Chi-square matrix showing the positive and negative species relations in Ogryudeung.

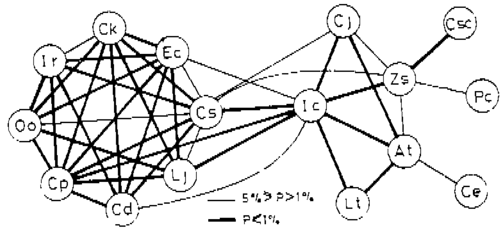

Fig. 14. Species diagram based on the chi-square value in Ogryudeung. Refer initial symbols to the plant names in Fig. 13.

sparsely. However, the prostrate habit is replaced with an erect one in Baeghapdeung and Ogryudeung with increasing plant density. In dune areas on both Baeghapdeung and Ogryudeung, *Lathyrus japonica* formed a mixed community with other plants (Figs. 5 and 6). This leguminous plant, with high nitrogen concentration (35 mg N/g of dry weight), seems to supply nitrogen to sand dunes.

Scirpus triqueter is distributed on mudflats which are exposed at low tide in Baeghapdeung and Ogryudeung. It has underground rhizomes and forms pure stands. Two major communities, *Phragmitetum communae* and *Caretum scabrifolae*, are developed in salt marsh. Associated with these, *Z. sinica*, *H. sibirica*, *Atriplex subcordata* and *Aster tripolium* are found.

In the species diagrams of Baeghapdeung and Ogryudeung (Figs. 12 and 14), *I. cylindrica* var. *koenigii* maintains positive association with the plants both of sand dune and salt marsh. This has been assertained through field observation. *I. cylindrica* var. *koenigii* showed the highest ecological performances at the intermediate zone between sand dune and salt marsh. The incomplete rings of the species diagram of salt marsh plants in Baeghapdeung and Ogryudeung (Figs. 12 and 14) indicate that the component species are not highly inter-correlated. In the species diagram of Baeghapdeung (Fig. 12), *S. komarovi*, pioneer species of sand dunes, shows positive association with other sand dune species. This is indirect evidence that the developmental stage of vegetation in Baeghapdeung is later than that in Ogryudeung, even if they have similar physiognomy. The positive associations among the plants in the species diagram of Namusitdeung (Fig. 8) are weaker than those of Galmaegideung (Fig. 10). This also indicates that the formation of vegetation in Galmaegideung precedes that in Namusitdeung. The foregoing results on plant community development coincide with the order of successional stages of each sand bar previously determined by Mun and Kim (1985).

摘　　要

洛東江 河口에 형성되어 있는 砂洲의 現存自然植生圖를 작성하였고 開拓者 植物의 定着으로 시작되는 植生의 형성과정과 association 分析으로 種間相關을 밝혀 同 砂洲의 遷移程度를 비교하였다.

조사지의 主要 開拓者 植物은 수송나물과 우산잔디이었는데 이들에 의한 砂丘의 형성과 植生의 발달과정은 밀접한 상호의존 관계를 보였다. Association分析의 결과 나무싯등과 갈매기등의 植生은 砂丘性 植物群과 1年生 또는 多年生 廣葉草本群으로 대별되었고, 백합등과 옥류등의 植生은 砂丘性 植物群과 鹽濕地性 植物群으로 대별되었으며, 이들 植物群의 分布는 現存自然植生圖와 잘 부합하였다. 식생발달을 기준으로한 각 砂洲의 遷移程度는 식물의 種數, 土壤環境의 변화를 기준으로 한 遷移程度의 순서와 일치하였다.

REFERENCES

Agnew, A.D.Q. 1961. The ecology of *Juncus effusus* L. in North Wales. *J. Ecol.* **49**: 83-102.

Chapman, V.J. 1964. Coastal vegetation. Macmillan, N.Y. 245pp.

Gemmell, A.R., P. Greig-Smith and C.H. Gimingham. 1953. A note on the behaviour of *Ammophila arenaria* (L.) Link in relation to sand dune formation. *Trans. Bot. Soc. Edinb.* **36**:132-136.

Goodall, D.W. 1953. Objective methods for classification of vegetation. I. The use of positive interspecificic correlation. *Aust. J. Bot.* **1**:39-63.

Hewett, D.G. 1970. The colonization of sand dunes after stabilization with marram grass (*Ammophila arenaria*). *J. Ecol.* 58:653-668.

Ishizuka, K. 1961. Ecological studies on the vegetation of coastal sand bars. I. An analysis of vegetation on a recently formed sand bar. *Ann. Rep. Gakugei Fac. Iwate Univ.* **19**: 37-64.

Küchler, A.W. 1967. Vegetation mapping. Ronald Press Company. N.Y. 472pp.

Laing, C. 1954. The ecological life history of the marram grass community on lake Michigan dunes. Ph. D. dissertation, Univ. of Chicago.

Mun, H.T. and J.H. Kim. 1985. Studies on plant succession of sand bars at the Nagdong River estuary I. Vegetation and soil environment. *Korean J. Bot.* 28:79-93.

Nicholson, I.A. 1952. A study of *Agropyron juncetum* (Beauv.) in relation to the stabilization of coastal sand and the development of sand dunes. M. Sc. Thesis, Univ. of Durham.

Oosting, H.J. 1956. The study of plant communities (2nd ed.). Freeman and Company. San Francisco. 440pp.

Ranwell, D.S. 1972. Ecology of salt marshes and sand dune. Chapman and Hill. London. 258pp.

Saito, K., K. Yoshioka and K. Ishizuka. 1965. Ecological studies on the vegetation of dunes near Sarugamori, Aomori Prefecture. *Ecol. Revi.* **16**:163-180.

Zedler, R.W. and P.H. Zedler. 1969. Association of species and their relationships to microtopography within old-fields. *Ecology* **50**:432-442.

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