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Plant Settlement Patterns and Their Effects on Breeding Sites of Little Terns (*Sterna albifrons*) on Sand Bars on Ganwol Lake

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ABSTRACT: We analyzed soil characteristics, soil seed banks, and plant communities in a small islet in Ganwol Lake from May 2005 to August 2006 to examine the forces driving plant settlement on sand bars and the effects of plant settlement patterns on nesting sites of little terns (*Sterna albifrons*). The soil nutrients contents in a site where the feces of wintering birds accumulate (N: 15.4 mg/kg, P: 10.5 mg/kg, LOI: 0.51%, pH: 6.8) and a site where organic sediments accumulate (N: 20.7 mg/kg, P: 16.4 mg/kg, LOI: 0.40%, pH: 6.6) were much higher those of a control site which was not affected by bird feces and organic sediments (N: 4.1 mg/kg, P: 5.4 mg/kg, LOI: 0.41%, pH: 6.7). However, a seed bank was formed only on the site with accumulated organic sediments. Plant settlement was accelerated by feces from wintering birds and organic sediment accumulation on sand bars in Ganwol Lake. The percentage of area disturbed by human activities increased from 0.2% in May 2005 to 13.9% in August 2006, and the percentage of annual communities increased from 27.5% to 43.3%, but the percentage of open area decreased from 55.2% to 28.0% from May 2005 to August 2006. These increases in disturbed area and annual communities decreased the open area for breeding of little terns. The enlargement of *P. communis* and *T. angustata* communities was suppressed by irregular flooding. These results provide useful information for the management of little tern breeding sites for conservation purposes.

Key words: Breeding site, Feces, Ganwol lake, Plant settlement, Sand bars, *Sterna albifrons*

INTRODUCTION

A sand bar is an ecological ecotone forming an area of transition between aquatic and terrestrial ecosystems. Habitats on coastal sand bars vary due to several factors, including the invasion of seawater. Ganwol Lake was formed by the construction of a seawall as a part of a farmland expansion program in 1995 (Cho et al. 2001). Seawalls have a direct effect on the movement and distribution of coastal sediments (Pye 1982). Once a sand bar is formed and becomes stable, plant succession proceeds through an open area stage, an annual-plant-dominated stage, a perennial-plant-dominated stage, and so on (Mun and Kim 1985a). Although there have been several studies on plant succession on sand bars (e.g., Mun and Kim 1985a, b), the relationship between plant settlement and bird breeding on sand bars has not yet been evaluated.

Little terns are distributed throughout coastal areas of the Korean peninsula, (Won 1981, Tomek 1999) and breed on sand bars in river estuaries, especially the Nakdong River Estuary and Ganwol Lake of Chunsoo Bay (Hong 1997, Park 2002, Kim 2007). Little terns generally complete their breeding before the rainy season on Chunsoo Bay, but frequent flooding from heavy rain often causes breeding failure (Kim 2007). Flooding not only disrupts nests but also changes the characteristics of breeding sites. Little terns prefer to breed in areas of low vegetation cover (Kim 2007), and flooding can affect the nutrient conditions of the soil. Changes in soil nutrient content in turn result in changes in the plant community (Croker and Dickson 1956, Olson 1958). To understand the early seral stage of an area of marshland, the plant species distribution, vegetation patterns, plant reproductive strategies, and soil seed bank composition and viability must be characterized (Leck and Graveline 1979).

In this study, we assessed the forces driving patterns of plant settlement and the effects of early plant settlement on sand bars on breeding of little terns. The specific objectives were to investigate changes in the vegetation and soil characteristics of sand bars before and after the rainy season, and to predict changes in the habitat of little terns on sand bars. The results of this study provide useful information for the management of little tern breeding sites for conservation purposes.

STUDY AREA

Seosan area A is located at 36°37'01"N, 126°27'40"E. The

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Ganwol Lake area in which area A is located includes artificial lakes and reclaimed farm lands (Fig. 1). The area has become one of the greatest wintering sites for Korean birds following construction of a dike (Cho 2003). After construction of the dike, the salt concentration decreased to 0.1%. Dominant plant species in Seosan area A are *Oryza sativa, Phagamites communis,* and *Typha orientalis.* There were 18 plant species (Table 1) in the small islet comprising the study area, and dominant species were *P. communis* and *T. angustata*.

Large quantities of grain remain in the vast farmland after harvest, which become food sources for wintering water birds such as Baikal teals (*Anas formosa*) (Cho 2003). Feces of wintering water birds then accumulate in the study area (JM Nam, personal observation). Little terns, Kentish plovers (*Charadrius alexandrinus*) and oystercatchcers (*Haematopus ostralegus osculans*) use sand bars of small islets in the lake as breeding sites (Cho 2003, Kim 2007). The size of the small islet studied is about 16,500 m^2.

The average temperature in the study area is higher than inland temperatures at the same latitude due to the influence of ocean currents (Cho 2003). Mean annual precipitation is 3,814 mm and 73% of precipitation falls between June and September (Fig. 2). The monthly precipitation in May 2005 was 56 mm in the study area, 855 mm of rain fell from May to July 2006, and 58 mm fell in August 2006. The lake water level was regulated by the embankments for farmland. Sand bars were frequently flooded in this period, because the floodgate was opened only in ebb tides.

Table 1. Plant species on the study islet

No.	Species
1	*Artemisia selengensis*
2	*Aster subulatus*
3	*Chamaecrista nomame*
4	*Chelidonium majus* var. *asiaticum*
5	*Chenopodium album* var. *centrorubrum*
6	*Cyperus amuricus*
7	*Draba nemorosa* var. *hebecarpa*
8	*Humulus japonicus*
9	*Lactuca indica* var. *laciniata*
10	*Lepidium apetalum*
11	*Oenothera odorata*
12	*Persicaria hydropiper*
13	*Persicaria lapathifolia*
14	*Phragmites communis*
15	*Portulaca oleracea*
16	*Rumex crispus*
17	*Scirpus lacustris*
18	*Typha angustata*

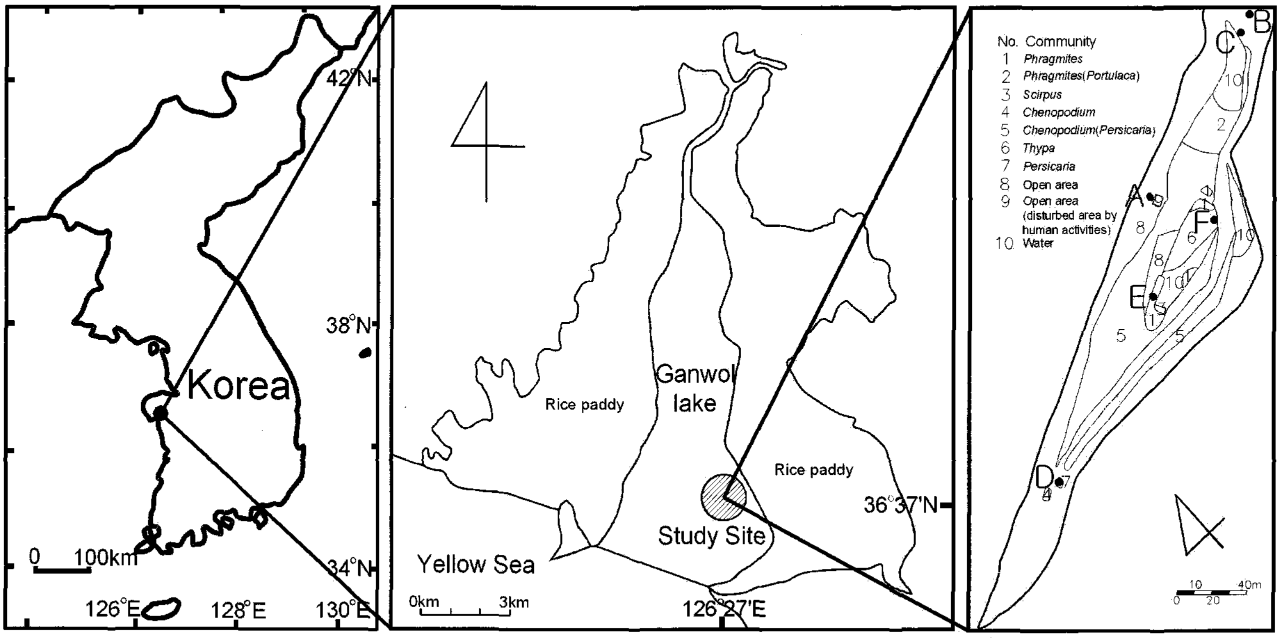

Fig. 1. Study area and sampling sites. A: Open area (control site), B: Open area (pile of bird feces), C: Open area (accumulation of organic sediments), D: Annual vegetation community, E: *Phragamites communis* community, F: *Typha angustata* community.

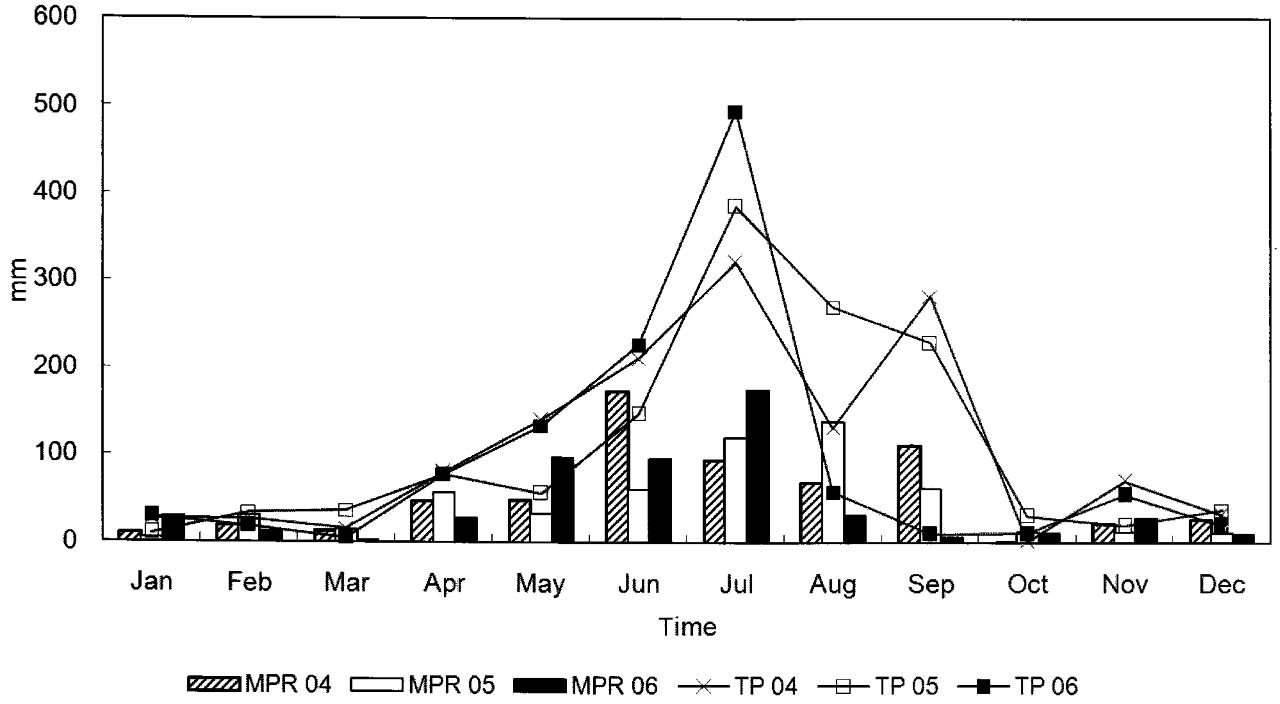

Fig. 2. Precipitation (mm) in the study area from 2004 to 2006 (data from the Seosan meteorological station). MPR: Maximum precipitation during a single rain event (series of rainy days), TP: Total precipitation.

METHODS

Sampling Sites

Based on a vegetation analysis in 2005, we selected 6 sites that differed in elevation and plant community. Sites A, B, and C were at lower elevation than other sites and were in open areas. Site A was composed of sand and used as control site. Wintering birds did not approach site A, because of the proximity of artificial structures to site A. Bird feces accumulated at site B, which is a resting area in winter. Site C was in an area that accumulated organic sediments because it formed a depression like a small puddle. Sites D and F were intermediate in elevation. Site D was in an annual plant community (*Aster subulatus* - *Persicaria lapathifolia* community) and site F was in a *T. angustata* community. Site F was saturated with water at all times and under shallow water after floods. Site E was at the highest elevation and therefore was less vulnerable to flooding than the other sites. The plant community was dominated by *P. communis*.

Soil Analysis

Five replicate samples of soil were collected at a depth of 0~5 cm from the surface at five of the six study sites in March, May, and August 2006 (sites A, B, C, E, and F, Fig. 1) and the replicates from each site were mixed (Kwon et al. 2006). We air dried the soil in the shade, and measured the NO_3-N, PO_4-P contents and pH of the soil. The pH of a mixture of 1 part soil and 5 parts distilled water was measured using a pH meter (Fisher, Model AP63). Water content was determined after drying the samples at 105 ℃ in an oven for 48 hrs after air drying (Topp 1993) and organic matter content was calculated as the mass lost after the samples were ignited in a muffle furnace at 550℃ for 4 hrs (Boyle 2004). NO_3-N was extracted with 2M KCl solution and analyzed using the Hydrazine Method (Kamphake et al. 1967). PO_4-P was extracted with Bray No.1 solution (Bray and Kurts 1945) and measured colorimetrically by the ascorbic acid reduction method (Solorzano 1969).

Soil Seed Bank Analysis

For soil seed bank analysis, soil cores 5.5 cm in diameter and 0~5 cm long were sampled on 4 March, 2006 at sites A, C, D, and E and preserved at 4℃ until 24 March, 2006, when a soil seed bank experiment was started. Soil was placed in polypropylene trays (40.0 × 23.5 × 10.0 cm) to a depth of 1 cm over a 3 cm layer of sterilized potting soil (Kim and Ju 2005). This inner trays were placed in outer trays (58.0 × 36.5 × 13.5 cm) in a greenhouse. One half of each core sample was submerged to a depth of 4 cm, and the other half in moist soil without standing water. All seedlings growing in the trays were identified after sufficient identifying characteristics had developed (Smith and John 1983).

Vegetation Survey

Vegetation surveys were conducted from May 2005 to August 2006. A vegetation map of the study islet was drawn and areas of cover of dominant species were calculated using Computer Aided Design (CAD 2007) programme. Dominance and sociability of plant species were recorded using the phytosociological method of Braun-Blanquet (Mueller-Dombois and Ellenberg 1974, Kim et al. 2004).

RESULTS AND DISCUSSION

Changes of Soil Characteristics with Plant Settlement Stage

Sites A, B, C, E, and F are representative of soils in the early plant settlement stages. In site B, 65.4 ± 30.5 g/m^2 of bird feces had accumulated from wintering birds. Nitrogen, phosphorus, and LOI concentrations in the bird feces were 30.1 mg/kg, 841.6 mg/kg, and 46.8%, respectively, which were much higher than those in soils at other sites in March (Fig. 3). Thus, site B, where wintering bird feces accumulated, contained more NO_3-N than site A. The increase in nutrient contents in site B could accelerate plant settlement on the sand bar (Crocker and Dickson 1956, Olson 1958, Mun and Kim 1985a). The soil in site C had higher level of nutrients than other sites in open areas because of the accumulation of organic sediments. Soil in site C was saturated with water, which can accelerate settlement of hydrophyte-dominated communities such as cattails. Soils from the perennial community in site E had similar nutrient contents to soils from sites B and C. Because sites A, B, C, and E frequently flooded during the rainy season, nutrient levels in May might be lower than those in March. After flooding, NO_3-N and PO_4-P levels in soil decreased, but pH and organic matter were

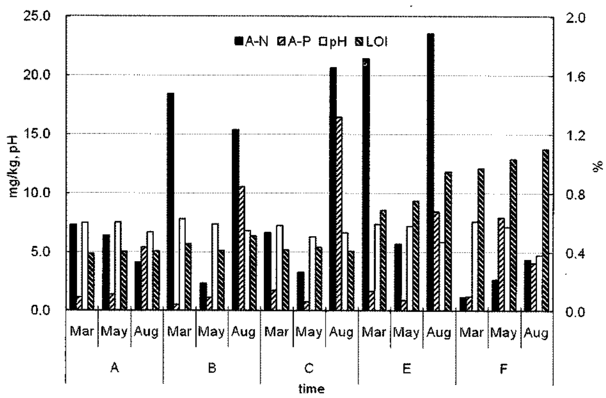

Fig. 3. Changes in soil characteristics at sites A, B, C, E, and F from March to August 2006. A-N: NO_3-N, A-P: PO_4-P, LOI: loss on ignition.

unchanged. In site F, the *T. angustata* community was saturated with water or flooded year-round, and nutrient levels were constant.

Soil Seed Bank Analysis

Soil seed bank samples were collected at sites A, C, D, and E, which are representative of the early plant settlement stages. No seed germinated in soils from site A and only three seeds from site C germinated under wet conditions (Fig. 4). Thus site C has some potential to develop an annual plant community. Sites D and E had relatively good seed banks. Plant communities in these sites had apparently developed for several years and in the early plant settlement stage, seeds of ruderal species had been stored in the soil. However, *P. communis* seeds did not germinated in site E as had been suggested by Kim and Ju (2005). Even when *P. communis* communities had a lot of *A. subulatus* and *P. lapathifolia* seeds in their soils, *P. communis* can remain dominant because it propagates by rhizomes. In site F, *T. angustata* was the dominant species, and many *T. angustata* seeds were found in the soil (Kim and Ju 2005), suggesting that this community will be sustained.

Effects of Seasonal Changes in Plant Distribution on Nesting Sites of Little Terns

The relative size of open habitat within the study area decreased from 55.2% in May 2005 to 28.0% in August 2006 (Fig. 5), whereas the total size of areas dominated by annual plants and disturbed by human activities such as boating, fishing, and discarding fishing nets gradually increased with time. Because little terns prefer to use open areas for breeding, enlargement of areas dominated by annual plants is a serious problem for little terns (Kim 2007).

Because the little tern breeding season is from April to June, the growth form of plants will affect the bird population most during this period. The birds prefer to breed on sand and the spread of plants into open areas hinders its breeding (Table 3). It can not breed in perennial plant communities such *P. communis* and *T. angustata* (Cho 2003, Kim 2007). Because perennial plants have a large below-ground biomass where they store nutrients, they can start to grow earlier than annual plants. However, in this study, we did not detect a rapid expansion of perennial plant communities (Fig. 5) and these plants did not cause a serious problem by reducing the open area available for breeding birds. *Phragmites communis* can proliferate only in regularly flooded areas during its growth period and this type of habitat was restricted to site F in 2006 (Table 2). However, *T. angustata* can grow well only in saturated areas or areas flooded by shallow water (Lee et al. 2007) and therefore could not extend its habitat.

Irregular flooding might restrict the enlargement of *P. communis* and *T. angustata* communities and therefore have a positive effect

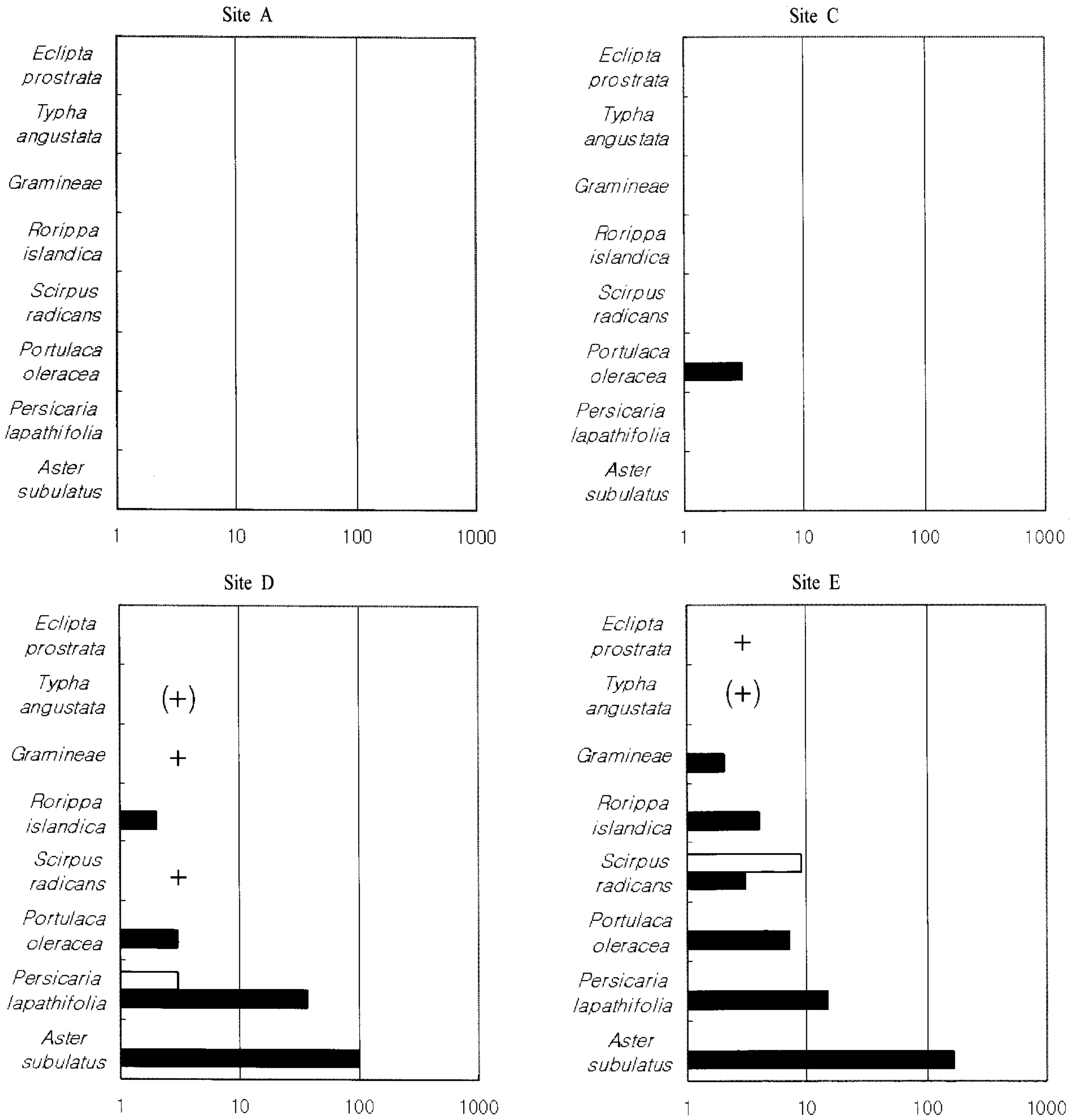

Fig. 4. Seeds from soils from sites A, C, D and E (log scale). White bar: seeds growing in the submerged condition, Black bar: seeds growing in the wet condition, '+' indicates one individual.

on breeding little terns. However, flooding also leads to accumulation of organic sediments on areas of low elevation such as site C (Fig. 3), which allows *Portulaca oleracea* communities to develop in open areas (Table 2). Therefore, the area of open habitat for breeding of little terns has decreased on the sand bars.

CONCLUSIONS

Flooding leads to the accumulation of organic sediments and seeds and accelerates the development of annual plant communities in open areas of sand bars. Feces from wintering birds might also accelerate early plant settlement. While the area disturbed by human activities and the area occupied by annual plant communities rapidly increased, the area of relatively open habitat on sand bars, the preferred little tern breeding habitat, decreased. Enlargement of *P. communis* and *T. angustata* communities, where little terns could not breed, is suppressed by irregular flooding. These results suggest that little terns will benefit from flooding of their breeding sites

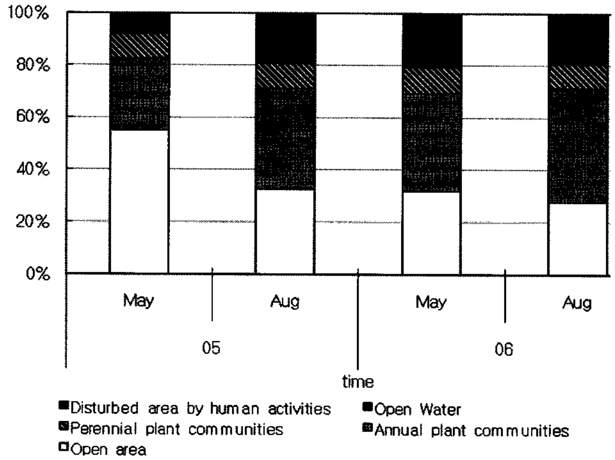

Fig. 5. Changes in the percentage of area in each category from 2005 to 2006.

even after June. This management will reduce the NO_3-N and PO_4-P contents of the soil and destroy plant communities, resulting in delayed plant settlement without negatively affecting bird populations. Alternatively, the plant communities should be removed before the bird breeding season.

Table 3. Comparison of vegetation cover (mean ± se) in areas with *Sterna albifrons* nests vs. random points from 24 April to 28 May 2005 (from Kim 2007)

Variables	Nest spot (n=43)	Random spot (n=25)	p[a]
Cover within 0.5 m (%)	1.4 (0.6)[b]	12.6 (2.6)	<0.001
Cover within 1 m (%)	9.9 (2.4)	15,4 (2.0)	<0.005

[a]. Mann-Whitney U test
[b]. Standard error

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Table 2. Floristic composition table for plants on the study islet

Community type	Open area									Annual plant community			Perennial plant community					
	A			B			C			D			E			F		
Site	05	06	06	05	06	06	05	06	06	05	06	06	05	06	06	05	06	06
Time	May	May	Aug	May	May	Aug	May	May	Aug	May	May	Aug	May	May	Aug	May	May	Aug
Number of species	0	0	0	0	0	0	0	0	1	2	3	2	2	3	5	1	2	2
Differential species of community																		
Persicaria lapathifolia										3.3	1.1	+		1.1				1.1
Chenopodium album var. *centrorubrum*										+	1.1	+		+				
Aster subulatus											2.2	3.3			1.1			
Phragmites communis													4.4	5.4	4.4			
Portulaca oleracea									3.2						1.1			
Rumex crispus													1.1					
Typha angustata																4.4	3.3	4.4
Scirpus lacustris																	1.1	
Artemisia selengensis															+			
Cyperus amuricus															+			

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