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Breeding Site Preferences and the Effects of Breeding Black-crowned Night Herons (*Nycticorax nycticorax*) on Soil Characteristics at Bamsum Island in Seoul

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ABSTRACT: Nest density was determined and tree and soil characteristics around *Nycticorax nycticorax* breeding sites and non-breeding sites on Bamsum Island in Seoul were analyzed from May 2005 to October 2006 to identify breeding site preferences of *N. nycticorax* and the effects of *N. nycticorax* nesting density on nesting tree structure and soil characteristics. *N. nycticorax* preferred trees of low height (3.5～6 m) and small diameter at breast height in high density *Salix* communities. Excrement of heron juveniles was dropped on the soil under the nests. The soil nutrient content under nests (P: 126.0 mg/kg, N: 202.8 mg/kg, EC: 549 μS/cm, pH 4.7) was much higher than that of control soils from Bamsum Island not enriched by heron excrement (P: 41.5 mg/kg, N: 42.0 mg/kg, EC: 342 μS/cm, pH 5.1). Formation of *Salix* communities on the shores of Bamsum Island is ongoing, and their structure has been directly influenced by annual flooding. After flooding, the nutrient content differences between heron-affected soils and control soils were not significant. This might be the reason that *Salix* communities on Bamsum were not affected by nesting herons as in other terrestrial communities where herons nest. This result indicates that flooding plays an important role in sustaining *Salix* communities on Bamsum Island where herons nest. The results of this study may increase understanding of *N. nycticorax* breeding behavior which may be useful for conservation planning.

Key words: Bamsum Island in Seoul, Breeding sites, Excrement, Flooding, *Nycticorax nycticorax*, *Salix* communities

INTRODUCTION

Birds use behavioral mechanisms to choose their habitats and individual movements are an essential component of the resulting habitat selection. Two kinds of factors must be considered in discussing habitat selection: evolutionary factors conferring survival value on habitat selection and behavioral factors providing the mechanism by which birds select areas. Habitat selection occurs as a result of stimuli from the landscape and terrain (Cody 1985). Selection by mobile individuals such as migratory birds occurs in a hierarchical manner from a larger spatial scale to the local microhabitat (Hutto 1985). Colonial breeding birds are generally crowded in the best habitats and found at low density in poor habitats as a result of intraspecific competition (Fretwell 1972). The birds compete for positions in good habitat, which can raise their breeding success rates.

Birds in the family Ardeidae arrive at breeding sites between March and early April and breed during summer in Korea (Won 1981). Nest heights of ardeids are affected by predation pressure (Fasola and Alieri 1992, Chung 2004). There is a positive correlation between flock size and food intake rate in herons (Moser and Schwagmeyer 1990, Fasola and Alieri 1992), which can be attributed to the tendency toward increasing bird density in habitats with good feeding conditions (Krebs 1974, Hafner et al. 1982, Cezilly et al. 1990). Factors affecting breeding site selection in ardeids include the plant type and structures for nesting sites, as well as breeding area, nest density, and the intensity of interspecific competition (McCrimmon 1978, Burger and Gochfeld 1990). Burkholder and Smith (1991) suggest that productivity in ecosystems where herons nest declines over time due to the loss of trees. Colonial breeding by birds in the family Ardeidae may also have a negative effect on primary productivity, soil nutrients and species composition of the herb layer in *Pinus densiflora* communities in breeding habitats (Mun and Cho 1996, Mun et al. 1996). Because the early seral stages with the most suitable vegetation develop into mature, less suitable stages (Fasola and Alieri 1992), active management of preferred vegetation types is necessary to ensure continual nesting by ardeids. Park and Won (1993) suggest that breeding sites of birds in the family Ardeidae should be protected from the human disturbance, especially during the breeding season. Ardeid species are highly dependent on wetlands, but also use a variety of habitats, including

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terrestrial and riverine forests. Even though *Salix* trees grow well alongside wetlands, a recent report states that herons also use *Salix* trees as nesting sites at Bamsum Island (Seoul city 2004). We found that herons have used *Salix* trees as nesting sites for several years on Bamsum Island. To maintain an appropriate structure of the *Salix* community for nesting herons, active management is necessary to prevent succession into less suitable plant communities.

The specific objectives in this study were 1) to characterize the structure of the trees which heron prefer for nesting sites, 2) to reveal the effects of heron breeding on soil characteristics, 3) to reveal the effects of flooding on soil chemistry under breeding trees. This study provides basic data which may be useful for the preservation of *Salix* communities as *Nycticorax nycticorax* breeding sites.

STUDY AREA

Bamsum Island, in central Seoul, was designated as a nature conservation area in 1998 (Fig. 1). In 1968, Bamsum Island was entirely destroyed by the removal of rocks and soil for use as construction materials. However, in the following decades, sediments settled down in the area again, and the island has grown. The present shape of Bamsum Island, which consists of two parts, was reached in 1986 with the completion of the overall development of the Han River (Han and Kim 2006). Bamsum Island is dominated by *Salix* spp., *Artemisia selengensis*, *Miscanthus sacchariflorus*, and *Phragmites communis* (Seoul City 2004). *Salix* community structure is directly influenced by annual flooding (Han and Kim 2006, Fig. 2). In addition to *N. nycticorax*, *Anas platyrhynchos*, *Anas poecilorhyncha*, *Phasianus colchicus*, *Paradoxomis webbiana* and *Acrocephalus arundinaceus* have also been observed breeding on Bamsum Island (Seoul City 2004).

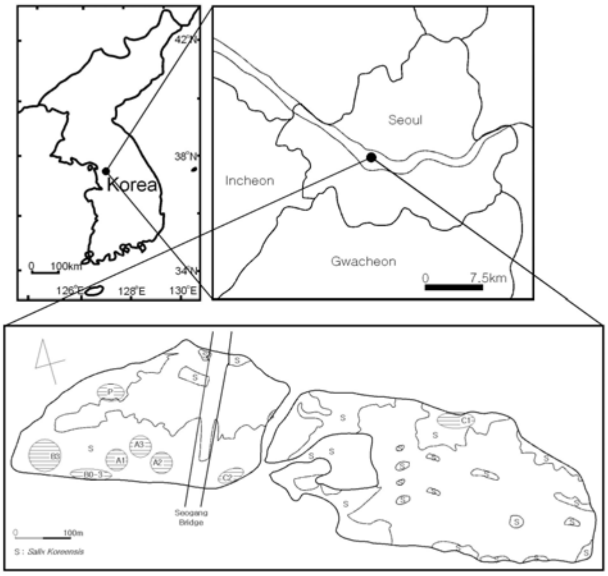

Fig. 1. Sampling sites on Bamsum Island in Seoul. S: *Salix* community. Area P was used as a breeding site until it was destroyed by flooding in 2001. Area A has been used as a breeding site since 2001, but was damaged by flooding in 2006. Area B1 has been used for breeding since 2003, and area B2 since 2002. Area C1 was used for breeding in 2006 but some trees were destroyed by flooding in 2006. Area C2 has not yet been used for breeding, but has appropriate tree characteristics for a breeding site.

METHODS

Nest Surveys and Nesting Tree Characteristics

This study was conducted on Bamsum Island from May 2005 to October 2006. We investigated the nest density of *N. nycticorax* in *Salix* communities and the changing history of *N. nycticorax* breeding sites through field and literature surveys. Based on survey results from 2005, eight quadrats in *Salix* communities were selected for additional study: three at high nesting density (area B), three at low nesting density (area A), and two in which no nesting occurred.

We investigated tree diameter at breast height (DBH), tree height, and tree density in eight quadrats in *Salix* communities (Fig. 1). Tree density was measured at breast height. Small *Salix* communities have formed annually in irregular patterns, generally parallel with the shore. Therefore, we used quadrats of different sizes to measure the characteristics of *Salix* trees of the same age; 13×21 m for site A1, 17×23 m for site A2, 9×10 m for site A3, 8×10 m for site B1, 4×10 m for site B2, 8×10 m for site B3, 4×5 m for site C1, and 5×9 m for site C2. We also used quadrats of different sizes for

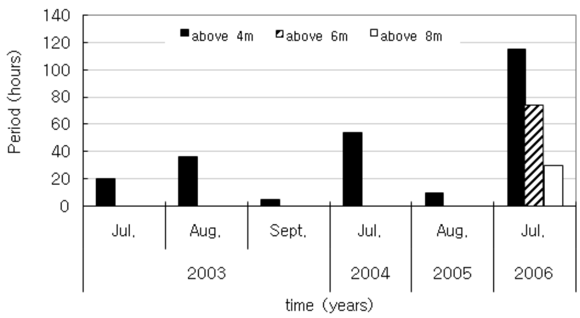

Fig. 2. Periods of flooding on Bamsum Island based on the water level at the Han Bridge. Bamsum Island begins flooding at a water level of 4 m, nests are threatened at 6 m and all *Salix* trees are submerged at 8 m. Data from Water Management Resources Information System http://www.wamis.go.kr

nest density surveys 20×45 m for site A1, 22×29 m for site A2, 25×30 m for site A3, 4×30 m for site B1, 8×30 m for site B2, 35×60 m for site B3, 5×20 m for site C1, and 5×30 m for site C2.

To compare differences in breeding site preferences and soil characteristics, we employed the paired-samplet-test and a standardized two sample *t*-test using S-plus software.

Soil Analysis

We collected five replicate soil samples at a depth of 0∼5 cm from the surface from each quadrat and mixed them (Kwon 2006). Electron conductivity, pH, NO_3-N and PO_4-P were measured in fresh soil, and the remaining soil samples were air-dried in the shade. Conductivity and pH (soil:distilled water = 1:5) were measured using a conductivity meter (Corning, Model 311) and a pH meter (Fisher, Model AP63), respectively. The 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 amount of weight lost after the samples were ignited in a muffle furnace at 550℃ for 4 hrs (Boyle 2004). NO_3-N was extracted with a 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).

RESULTS AND DISCUSSION

Nest Density of *N. nycticorax* in *Salix* Communities

The main nesting area of *N. nycticorax* in 2001 was area P, but at the time of this study, area P was not used any more, due to the loss of many *Salix* trees as a result of flooding in 2001. In 2002, the main nesting area shifted to areas A, and B (Seoul City 2004).

Even though all three quadrats in area A were used by nesting herons in 2005, only the A1 quadrat was used in 2006. The *Salix* community in the A2 and A3 quadrats were destroyed by flooding in 2006, making these areas unsuitable for nesting herons. The nest density in area A was also lower in 2006 (25 ± 43 nests/ha) than in 2005 (60 ± 19 nests/ha) (p = 0.083, Fig. 3, Table 1). On the other hand, the nest density in area B in 2005 (329 ± 149 nests/ha) was similar to that in 2006 (339 ± 140 nests/ha) (p = 0.9496), which indicates that the characteristics of area B made it a popular breeding site for these two years. These observations suggest that since 2002, the herons have preferred area B to area A.

Quadrats C1 and C2 were expected to become breeding sites in 2006 because the *Salix* trees in those areas had similar characteristics to those of area B (Table 2). Indeed, *N. nycticorax* started breeding in the C1 quadrat in 2006 as expected. However, the C2 quadrat was not used as a breeding site in 2006. This might be due to the location of C2, which is within 15 meters from Sogang bridge. Maeda (2005) has suggested that 50 meters is the minimum safe nesting distance from areas of human activity for ardeids.

Salix Community Characteristics

The differences in tree height, DBH, density and D^2H between the *Salix* communities in areas A and B (Fig. 3) were not statistically significant. The average height (5.8 m), DBH (8.3 cm), density (40.8 trees/100 m^2) and D^2H (398 cm^3) of *Salix* communities in area A in 2005 increased to 6.9 m, 9.7 cm, 15.4 trees/100 m^2, and 611 cm^3 in 2006, respectively. These changes might be the reason for the decreased heron nest density. The average height (4.1 m), DBH (4.3 cm), density (51.3 trees/100 m^2), and D^2H (89 cm^3) of *Salix* communities in area B in 2005 increased to 5.4 m, 7.4 cm, 24.6 trees/100 m^2, and 291 cm^3 in 2006, respectively. Even though there were changes in community characteristics in area B as in area A, the nest density of *N. nycticorax* was similar in 2006 and 2005. These results suggest that *N. nycticorax* on Bamsum Island prefer communities with high tree density (> 24.6 trees/100 m^2), and smaller tree height (< 5.8 m) and DBH (< 8.3 cm).

The mean tree height in quadrat C1 in 2006, when herons started breeding in C1, was 4.5 m. The main breeding sites of herons on

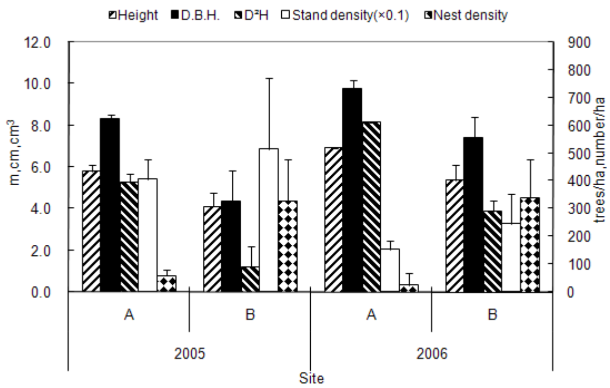

Fig. 3. Comparison of *Salix* communities properties in areas A and B in 2005 and 2006. All data are presented as mean ± SD.

Table 1. Comparison of nest density (mean ± SE) in areas A and B from 2005 to 2006

Variables	2005	2006	p^a
A area (number/ha)	60.3 (19.1)	24.7 (42.7)	0.087
B area (number/ha)	328.7 (148.5)	339 (140.0)	0.950
p^b	<0.05	<0.05	

[a] Paired *t*-test.

[b] Standardized Two-Sample *t*-test.

Table 2. *Salix* community properties at study sites in Bamsum Island

Year	Site	Height (m)	D.B.H. (cm)	D^2H (cm^2)	Stand density (trees/ 100 m^2)	Distance from bridge (m)	Nest density (number/ ha)
2005	B1	3.5	3.2	35	80.0	>100	250
	B3	4.8	6.0	174	43.8	>100	236
	C1	4.0	3.4	46	197.4	>100	0
	C2	4.0	6.9	193	108.9	15	0
2006	B1	5.4	7.0	265	36.3	>100	500
	B3	6.1	6.7	273	22.5	>100	267
	C1*	–	–	–	–	>100	>100**
	C2	5.0	7.0	245	62.2	15	0

*: destroyed by flooding in 2006, **: Nest density is before flooding.

Bamsum Island from 2001 to 2004 shifted from area P to areas A and B and the mean tree height in each area when herons started using the area for breeding was around 3.5 m (Seoul City 2004). Based on this observation, we suggest that *N. nycticorax* start breeding in *Salix* communities when the mean tree height is around 3.5 m and the canopy is closed. While *N. nycticorax* started breeding in *Salix* communities of mean height 3.5 m on Bamsum Island, birds of the family Ardeidae generally prefer trees of greater height in other terrestrial communities (Kwon 2007, Chung 2004), probably because they confer greater protection from ground predators (Chung 2004). However, because Bamsum Island is surrounded by deep water and is flooded annually, there are no ground predators of the heron on the island. This might be the reason that *N. nycticorax* can use *Salix* communities on Bamsum with lower mean tree height. Accordingly, Chung (2004) found that in areas of low predation pressure, ardeids can breed in trees of low height, such as *Phyllostachys bambusoides* and *Sasa borealis* communities.

Nutrient Contents of Soil Change Which is Caused by with the Breeding

Salix communities were established in the sequence B3, B2, then B1. Fig. 4 shows the soil characteristics of these three quadrats in 2006. Organic matter and electron conductivity increased with the growth of *Salix* trees but NO_3-N, PO_4-P and pH did not change. Bird feces dropped by nesting herons on Bamsum Island increased the NO_3-N and PO_4-P content, conductivity and acidity of the soil, which is consistent with the results of previous studies (Mun and Cho 1996, Mun et al. 1996). The effect of feces on soil characteristics in other quadrats were the same as those in B1 (Figs. 5 and 6).

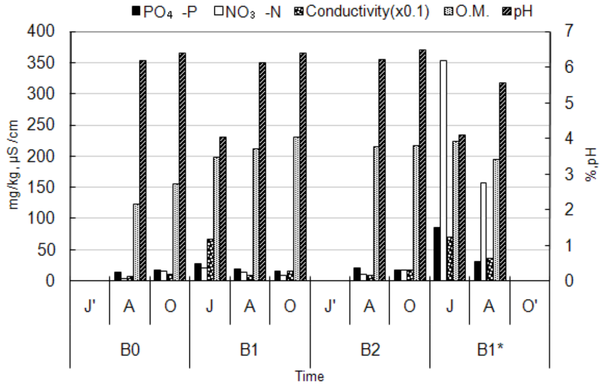

Fig. 4. Changes in soil characteristics in quadrats B0, B1 and B2 from June to October 2006. ': no sampling, *: included feces.

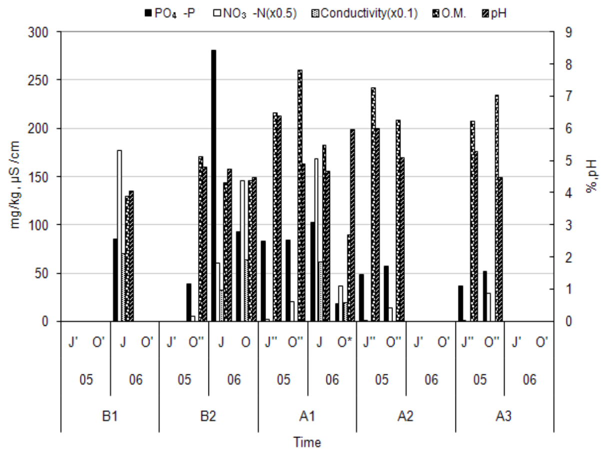

Fig. 5. Soil characteristics in breeding sites in areas A and B from 2005 to 2006. ': no sampling, '': no data of electron conductivity, *: excluded feces.

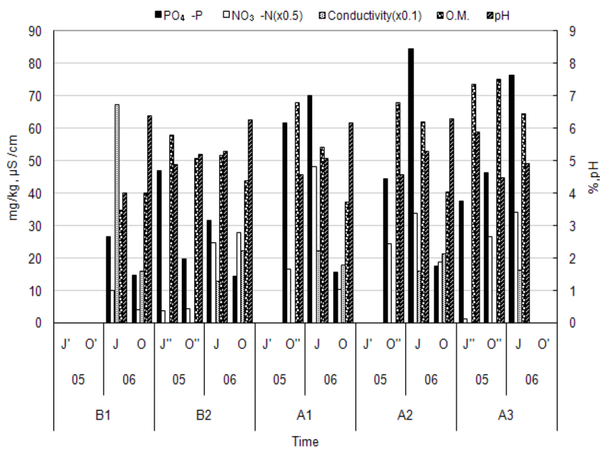

Fig. 6. Soil characteristics in control strands from 2005 to 2006. ': no sampling, '': no data of electron conductivity.

Soil PO_4-P content and conductivity on Bamsum Island were higher than those of *Salix* communities in the Nam River (Lee et al. 2001), and bird feces caused a greater increase in PO_4-P content (84.5 mg/kg), electron conductivity (207 μS/cm) and acidity (pH 0.4) on Bamsum Island.

However, the effects of bird feces on soil decreased in August and October following flooding in July or August. Although bird feces can have deleterious effects on plants in terrestrial ecosystems (Mun and Cho 1996), they apparently do not have a strong negative effect on *Salix* communities on Bamsum Island. On Bamsum Island, annual flooding removes the bird feces from the soil (Lee et al. 2001, Seoul City 2004, Lee et al. 2005). Flushing of bird feces as a result of flooding is the main difference between riverine and terrestrial ecosystems. On Bamsum Island, the annual flooding prevents accumulation of bird feces above ground and on the tree bole.

Bird feces might increase the growth rate of *Salix* trees, accelerating self-thinning and make them more susceptible to flooding. After the floods of 2001, many of the *Salix* trees in area P were dead. We do not know if their deaths resulted from prolonged flooding or self-thinning.

CONCLUSIONS

N. nycticorax prefers nesting in trees of low height (3.5～6 m) and small DBH in high density *Salix* communities in areas >50 m from the bridge on Bamsum Island. Bird feces deposited in nesting areas increased the PO_4-P content of the soil more than threefold, and the NO_3-N content more than tenfold, and decreased the pH to 4. However, these feces did not accumulate on the ground because of annual flooding. Therefore, bird feces have less deleterious effects on *Salix* communities than on terrestrial plant communities. *Salix* communities are very important for nesting herons on Bamsum Island. While nesting sites are less influenced by bird excrement on Bamsum than in other areas, *Salix* trees on the island grow and become less favorable trees for nesting over time. Therefore, to protect the local heron community, it is important to take measures to ensure the continual formation of new *Salix* communities.

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