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The Effect of Birds in the Families Ardeidae and Corvidae on Stand Structure in Bamboo Groves

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ABSTRACT: We investigated death rates, growth rates and recruitment of culms in two neighboring bamboo (*Phyllostachys bamboosoides*) stands nested in by two different bird species to analyze stand structure and to design conservation strategies. A third bamboo grove not used by birds, the Taewha stand, was included as a control stand. The bamboo stand occupied by birds in the family Ardeidae (the Ardeidae stand) had an approximately 1.5 times higher culm density than the stand occupied by birds in the family Corvidae (the Corvidae stand). The crude death rate and the number of newly emerged shoots were also higher in the Ardeidae stand than the Corvidae stand. The death rate for bamboo in the Ardeidae stand was not dependent on diameter at breast height (DBH) and was almost 40% for culms of all sizes, whereas most dead culms in the Corvidae stand were < 4 cm DBH. Consequently, we conclude that in the Ardeidae stand, density-independent causes of death are operating, while density-dependent factor are more important in the Corvidae site. The results of soil analysis in these stands suggest that the density-independent death pattern observed in the Ardeidae stand may be due to soil acidification resulting from wastes produced by the birds during breeding. On the other hand, the culm distribution and death patterns in the Corvidae stand suggest that the stand characteristics were not affected by the nesting birds. These results suggest that different conservation strategies must be applied to conserve bamboo groves used by ardeids and corvids for nesting.

Key words: Ardeidae, Bamboo grove, Corvidae, Culm, Stand structure

INTRODUCTION

Plant communities support a variety of animal life by supplying habitats and food, while plant communities are also affected by animal behavior. In particular, inhabitation by dense population so birds may affect plant community structure through environmental changes in the habitat (Moon et al. 1996a, b). This kind of interaction between animals and plants occurs across diverse areas and scales (Hairstone et al. 1960, Porter et al. 2002). In addition, interactions among plant species also affect plant community composition and dynamics (Fowler 1986, Keddy 1989, Goldberg and Barton 1992, Callaway and Pugnaire 1999). Plant population dynamics also affect habitat characteristics such as habitat structure and distribution, in which may determine the biodiversity in a given area (Dunning et al. 1992, Kobe 1996).

Bamboo is a monocarpic plant group that is distributed worldwide and includes about 1,000 species (Bystriakova et al. 2003). About 30 species are distributed in East Asia (Suzuki 1978, Bysriakova et al. 2003) and seven of these species are distributed in Korea (Kong 2001). The genus *Phyllostachys* belongs to a group of tall bamboo species and has traditionally been used in Korea as a material for house wares and food, and is used in many traditional ceremonies, such as weddings, funerals and ancestral worship rituals (Kong 2001). Thus, bamboo groves have been created around houses for a variety of purposes since the Chosun dynasty (Chung 1959), resulting in a coverage of 4,607 ha in 1938 (Cheong 1962). Bamboo groves have also been created on riversides in order to prevent flooding because bamboo can grow up to 15～20 m (Kim and Okuda 1993, Kong 2001). However, recently the area of bamboo groves in Korea has been reduced due to the development of substitute materials for house wares, as well as climate change and the conversion of bamboo groves into agricultural fields (Kong 2001). However, some bamboo groves are being preserved, such as the Taewha bamboo grove in Ulsan city, south-eastern Korea. A large area of bamboo groves remain along the Taewha River although some groves are being used as an eco-park. A great number of migratory birds in the families Ardeidae and Corvidae perio-

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dically arrive in this bamboo grove (Lee et al. 2006, 2008). However, a great number of bamboos in groves heavily used by ardeids have died, while bamboos in groves used by corvids do not show increased death rates (Lee et al. 2008). Further study is needed to clarify the causes of bamboo death and to develop a plan to conserve bamboo groves.

The objectives of this study are 1) to determine the differences in stand structure and new shoot recruitment systems between stands inhabited by ardeids and corvids and 2) to determine the factors affecting death rates in bamboo in both types of stands.

Study Sites

The study site is located on the riverside in the middle reaches of the Taewha River, which runs through Ulsan city in south-eastern Korea (35° 33' 56" N, 129° 16' 88" E). In this area bamboo (*Phyllostachys bambusoides*) groves that once reached 3.0 km in length have developed along both sides of the Taewha River (Lee 2005). However, their area of coverage has been reduced by land management plans made by the Ulsan city authority in both 1995 and 2001, and by conversion of some edges of the grove to farmland. As a result, one side of the bamboo grove, the Taewha grove, has been managed as an eco-park, whereas the other side, Samho bamboo grove, has been relatively well preserved. We chose the Taewha bamboo stand as a control site, as no birds inhabit the Taewha stand due to disturbance by human visitors. The Samho bamboo grove is 1.2 km long and about 30～80 m wide, and covers a total of about 9.0 ha (Lee et al. 2007). A great number of migratory birds in the families Ardeidae and Corvidae, have visited this bamboo grove every year. Visitors to the bamboo grove from the family include *Egretta garzetta*, the dominant species, *E. intermedia*, *E. alba modesta*, *Bubulcus ibis*, and *Ardea cinerea* (Lee et al. 2008). These species all breed in this grove and the estimated number of breeders reaches about 1,500 breeding pairs (Lee et al. 2007). Corvid visitors to the area mainly consisted of *Corvus frugilegus* and *C. dauricus*, and the estimated number of corvids visiting and resting in this grove annually ranges from about 20,000 to 35,000 individuals (Lee et al. 2007, 2008). Vegetation around the Samho bamboo grove consisted of common weed species such as *Digitaria sanguinalis*, *Eleusine indica*, *Paspalum thunbergii*, *Poa annua*, *Humulus japonicus*, *Boehmeria spicata*, *Boehmeria platanifolia* and *Bidens ripartita*. Inside the bamboo stands, the culm density is so high that other plant species could not grow.

The study was conducted in the Samho and Taewha bamboo groves (Fig. 1), and included stands in the Samho grove occupied by birds in the family Ardeidae (the Ardeidae stand) and stands occupied by birds in the family Corvidae (the Corvidae stand). Though ardeids and corvids inhabit the same grove, they segregate their habitats in space and time by inhabiting areas about 100 m apart and by visiting at different times. Ardeids nest on an edge of the grove, whereas corvids nest in the middle of the grove. In addition, ardeids use the bamboo grove as a breeding place from mid-May to the end of August and use it as resting place until the end of September, while corvids use the bamboo grove only as an over-wintering shelter from October to the end of March (Lee 2007). Some areas around the bamboo grove is being used as agricultural fields.

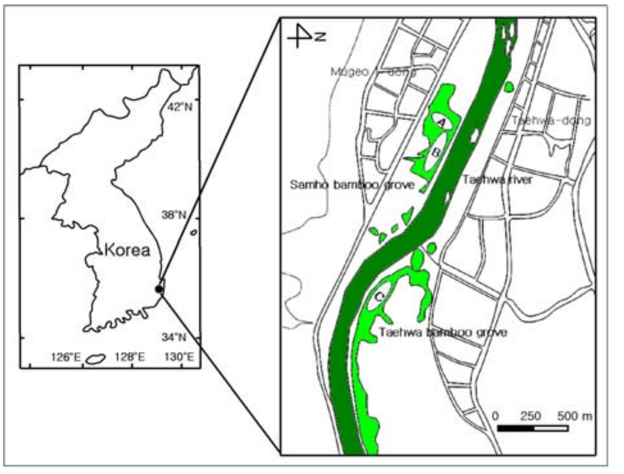

Fig. 1. Map showing the location of study stands in Ulsan city in south-eastern Korea. A, the Ardeidae nesting stand and B, the Corvidae staying stand in the Samho bamboo grove and C, the control stand in the Taewha bamboo grove.

MATERIALS AND METHODS

Air temperature and relative humidity were measured each day with a temperature and humidity measuring system (TU-72, technox, USA) at the height of 120 cm above the ground. Measurements were carried out during the midsummer breeding period for birds in the family Ardeidae and the visiting time for birds in the family Corvidae.

To analyze stand structure and population characteristics, three quadrats (10 × 10 m each) were established in each bamboo grove in May 2007. The number of living, dead and fallen bamboo individuals in each quadrat were counted in June 2007. Culm diameter at breast height (DBH) was measured with vernier calipers at the midpoint of an internode at breast height. Two measurements were made per culm with opposite directions to cover the uneven form of the culm, and the values were averaged.

The number of newly emerged culms in each quadrat was counted twice a week from May to June, the time of new culm emergence. Among the newly emerged culms, twenty culms about 30 cm in height in each quadrat were selected for monitoring of height and diameter changes. Culm height could be directly measured to a height of 3 m. Culm diameter was measured 5 cm from the soil surface. These measurements were taken repeatedly for 3 weeks after the time of culm emergence. The numbers of newly emerged shoots remaining undamaged until the last measurement was taken were 18, 18 and 8 in the Ardeidae stand, Corvidae stand and Control stand, respectively.

Differences among stands in culm density, number of dead culms, condition at the time of death (standing vs. fallen), number of newly emerged shoots and culm growth parameters were analyzed with ANOVA using SPSS (ver. 12.0).

RESULTS AND DISCUSSION

The Taewha stand, used as a control, had the highest air temperature and the lowest relative humidity among three the stands. We were unable to obtain climate data in the Taewha stand in May and August due to human disturbance of the temperature-measuring system (Fig. 2). The Corvidae stand had a higher mean air tempe-

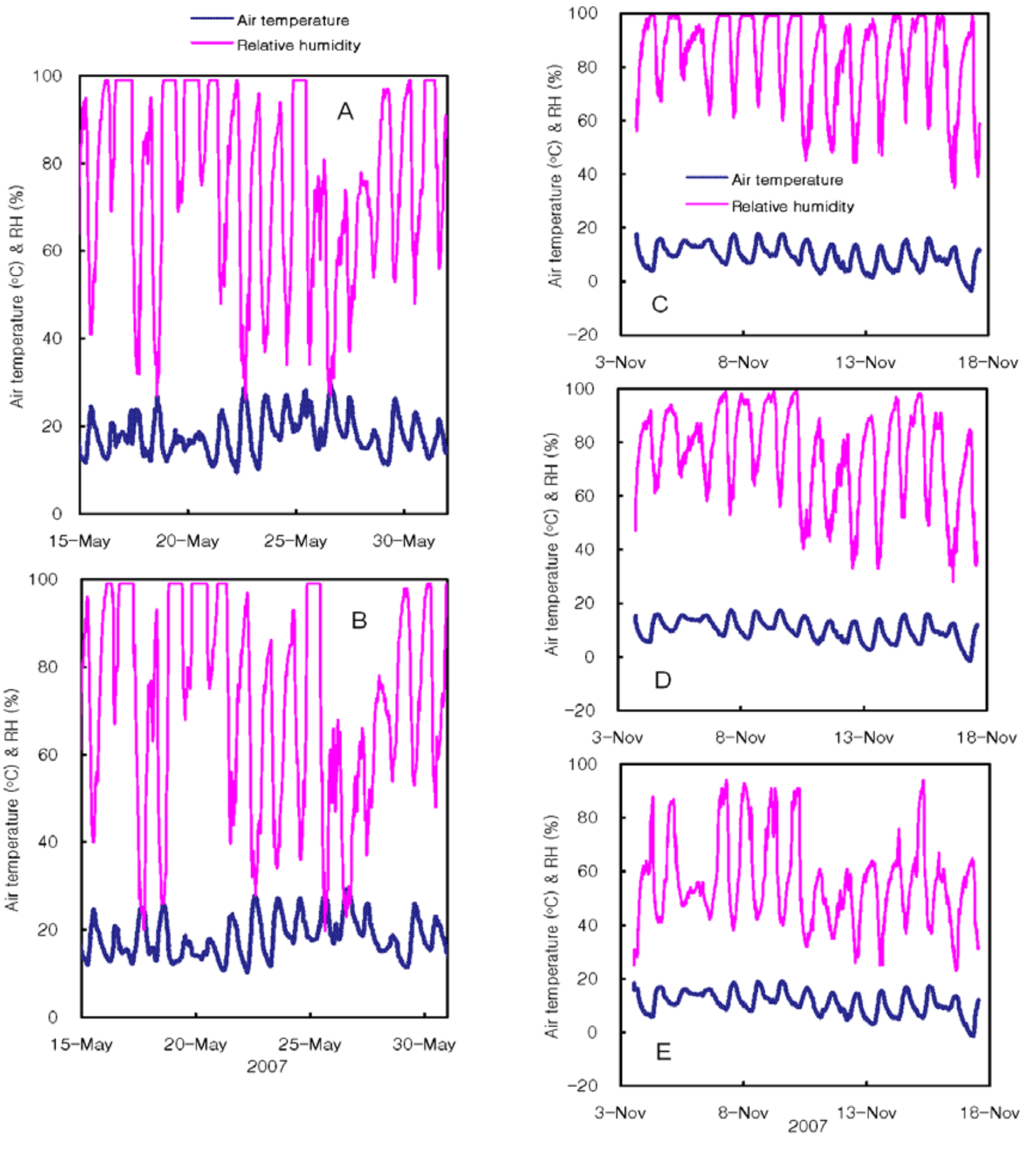

Fig. 2. Changes in the air temperature and relative humidity (RH) in the Ardeidae stand (A, C), the Corvidae stand (B, D) and the Taewha stand (E) in May (left) and November (right), the times of arrival for ardeidae and corvids.

rature and lower relative humidity from May through November than the Ardeidae stand, indicating that it was a drier habitat. These differences among sites may affect bamboo height growth because the most limiting factor affecting cell growth is plant water status (Boyer 1970).

Culm density varied among the stands (Fig. 3). Culm density in the Ardeidae stand was highest, at about 1.5 times of that in the Corvidae stand. The lowest density was found in the Taewha (control) stand. We also found a difference in the distribution of culm DBH size among stands (Fig. 4). In the Ardeidae stand, ~80% of culms were <4 cm DBH, whereas in the control stand, 82% of culms had DBH >4 cm and in the Corvidae stand, culm DBH sizes were normally distributed with a central peak and the lowest values on each end of the size distribution (Fig. 4). Therefore, on a graph, the culm size distribution in the Ardeidae is skewed to the left and that in the control stand is skewed to the right as compared with the DBH distribution in the Corvidae stand (Fig. 4). Normal distributions in DBH size are generally found in established and stable stands (Mohler et al. 1978), which suggests that visits by corvids hardly affect the population distribution of bamboo culms in the Corvidae stand. This may be because of the corvid habit having different nesting and foraging places (Lee and Park 1995). We assume that the corvids only rest in the Corvidae stand at night, and forage elsewhere during the day, resulting in little effect from their stay on the bamboo stands. On the other hand, in the control stand, the culm DBH distribution pattern was affected by artificial regulation to manage population size (Fig. 4). The number of dead culms in the stands was also highest in the Ardeidae stand and lowest in control stand (Fig. 5A). Death rates play an important role in determining population sizes (Kobe 1996). Despite the fact that the Ardeide stand showed the highest death rate among the stands, it nonetheless maintained the highest culm density as a result of relatively high recruitment of newly emerged shoots (Figs. 5A, 7). However, further study will be required to understand the underlying causes for the difference in death rates among stands. Two types of culm death were observed in all stands (Fig. 5B). The majority of culms died while standing in all three stands, but in the Ardeidae stand, about 30% of culms died after falling, whereas less than 10% of culms died after falling in other stands (Fig. 5B). The number of culms that died after falling in the control stand did not differ substantially from that in Corvidae stand (Fig. 5B). In addition, the Ardeidae stand and the Corvidae stand show distinct patterns of size-specific culm death rates (Fig. 6). In the Ardeidae stand, about 40% of culms in every DBH class died, whereas in the Cor-

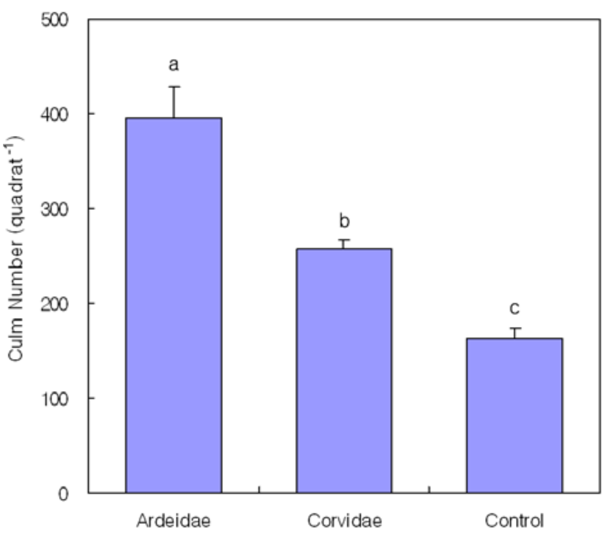

Fig. 3. Culm density in the Ardeidae, Corvidae and Taewha (control) stands. Data presented are means ± SE (n = 3). Different letters above the bars indicate significant differences ($P \leq 0.05$).

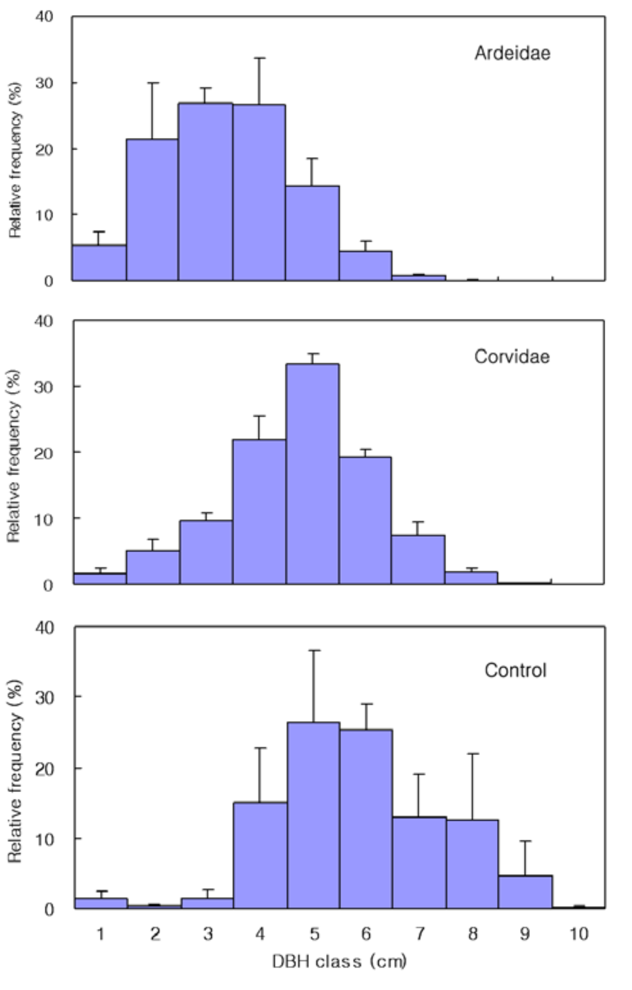

Fig. 4. Relative frequency distribution of diameter at breast height (DBH) of culms in the Ardeidae, Corvidae and Taewha (control) stands. Data presented are means ± SE ($n \geq 3$).

vidae stand, most culms < 4 cm in DBH died, while no culms > 7 cm in diameter died during this study, indicating size-dependent causes of death. From the results shown in Fig. 6, it is evident that different factors must affect culm death rates in the Ardeidae stand and the Corvidae stand. The cause of culm death in the Corvidae stand appears to be density-dependent, because the smaller the culm, the higher the death rate. On the other hand, in the Ardeidae site, the main cause of death must be density-independent, because death rates were similar over all culm sizes (Fig. 6).

To maintain these bamboo groves in their present state, the number of newly recruited shoots must be adequate to replace dead culms. In the three stands examined, the numbers of newly recruited shoots seem to be sufficient to maintain the population although there were some differences among stands (Fig. 7). However, if newly recruited shoots fail to grow normally or die early, population size could decline. Thus, the growth of newly emerged shoots plays an important role in maintaining the population size and determining stand structure. Interestingly, the growth rates of newly emerged shoots differed between the Ardeidae stand and other two stands (Fig. 8). In both the Corvidae and control stands, the diameter of the newly emerged shoots rapidly increased during the first three days and slowly increased thereafter, while in the Ardeidae stand, a smaller increase in the diameter of new shoots was shown for the first three days and the growth then leveled off to a significantly lower level than that of other two stands (Fig. 8). As a result, the shoot diameter of newly emerged shoots in the Ardeidae stand

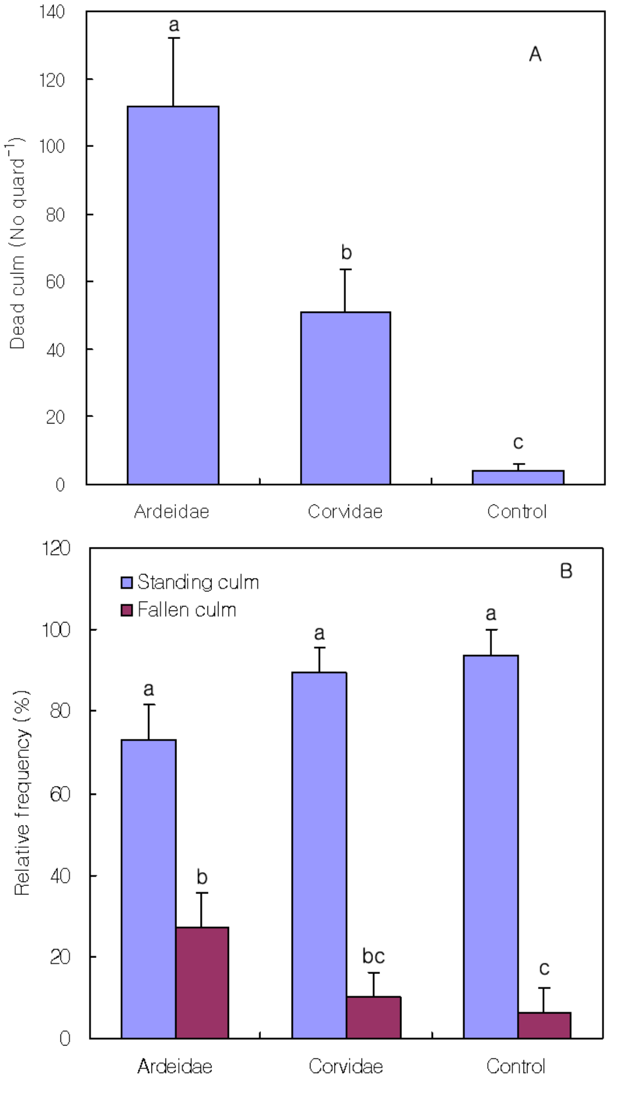

Fig. 5. Dead culm number (A) and condition at death (standing or fallen) (B) of culms in the Ardeidae, Corvidae and Taewha (control) stands. Data presented are means ± SE ($n \geq 3$). Different letters above the bars indicate significant differences ($P \leq 0.05$).

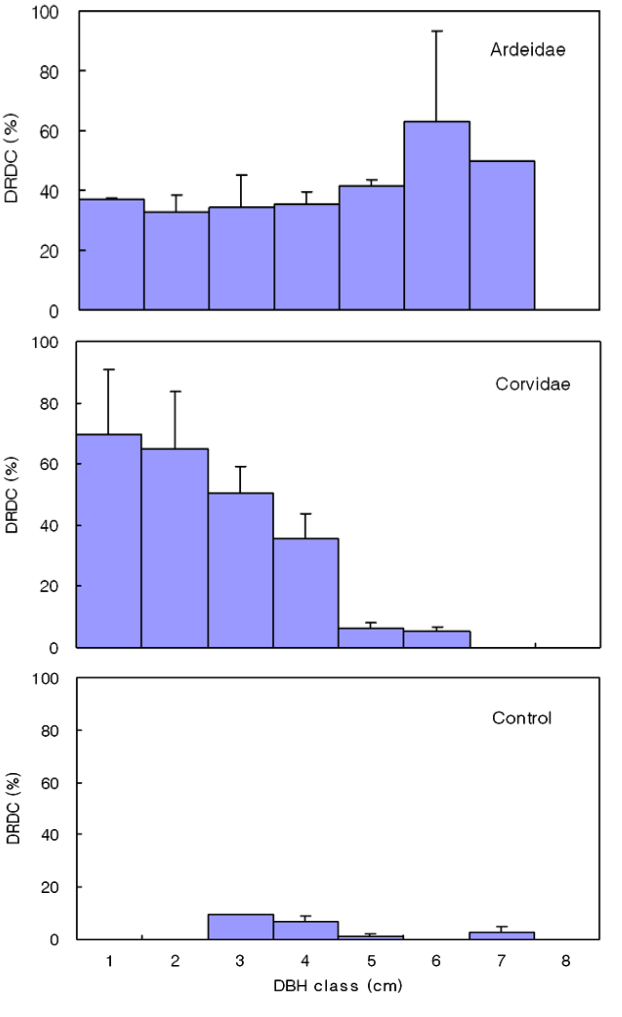

Fig. 6. Distribution of Death Rates per DBH Class (DRDC) of culms in the Ardeidae, Corvidae and Taewha (control) stands. Data are presented means ± SE ($n \geq 3$).

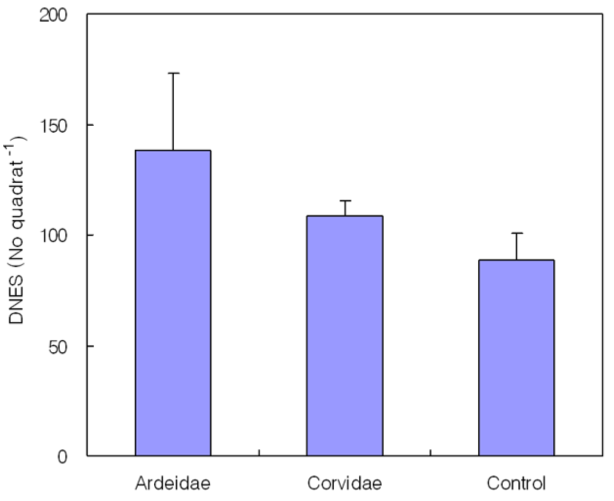

Fig. 7. Density of newly emerged shoot (DNES) in the Ardeidae, Corvidae and Taewha (control) stands. Data presented are means ± SE (n = 3).

increased to only 1.4 times their original size during the three-week experimental period as compared an increase to 2.1 times and 1.8 times original size in the control stand and the Corvidae stand. The growth in height of newly emerged shoots in the Ardeidae stand was also retarded as compared with those in the other stands. Shoot heights increased to 8.8 times, 9.9 times and 11.7 times the original height in the three-week experimental period in the Ardeidae, Corvidae and Taewha stands, respectively (Fig. 8).

Consequently, the Ardeidae stand was characterized by the highest culm death rate, nearly equal death rates for culms of all sizes, a relatively high rate of emergence of new shoots and the lowest growth rates in culm height and diameter. These facts suggest that in the Ardeidae stand ecological factors lead to density-independent death rates and limit the growth of newly recruited shoots. Considering the fact that the Ardeidae stand is only about 100 m away from the Corvidae stand, and that Corvidae bird inhabitation hardly affected stand structure in the Corvidae stand, we conclude that the factor causing density-independent death of bamboo culms in the Ardeidae stand may be related to inhabitation of the stand by ardeids**.** This inference is supported by the results of other studies. Herons in the family Ardeidae breed in groups in pine communities and larch forests. Breeding herons have been linked to the death of pine trees as well as changes in soil structure and community structure resulting from soil acidification from the introduction of bird wastes and litters mixed with wastes to the soil (Moon et al. 1996a, 1996b**)**. Lee et al. (2007) reported that soil in stands occupied by ardeids was acidified, with pHs from 3.6 to 4.4 in the top thirty centimeters of soil, while pHs in stands inhabited by corvids and control stands ranged from 4.5 to 5.3.

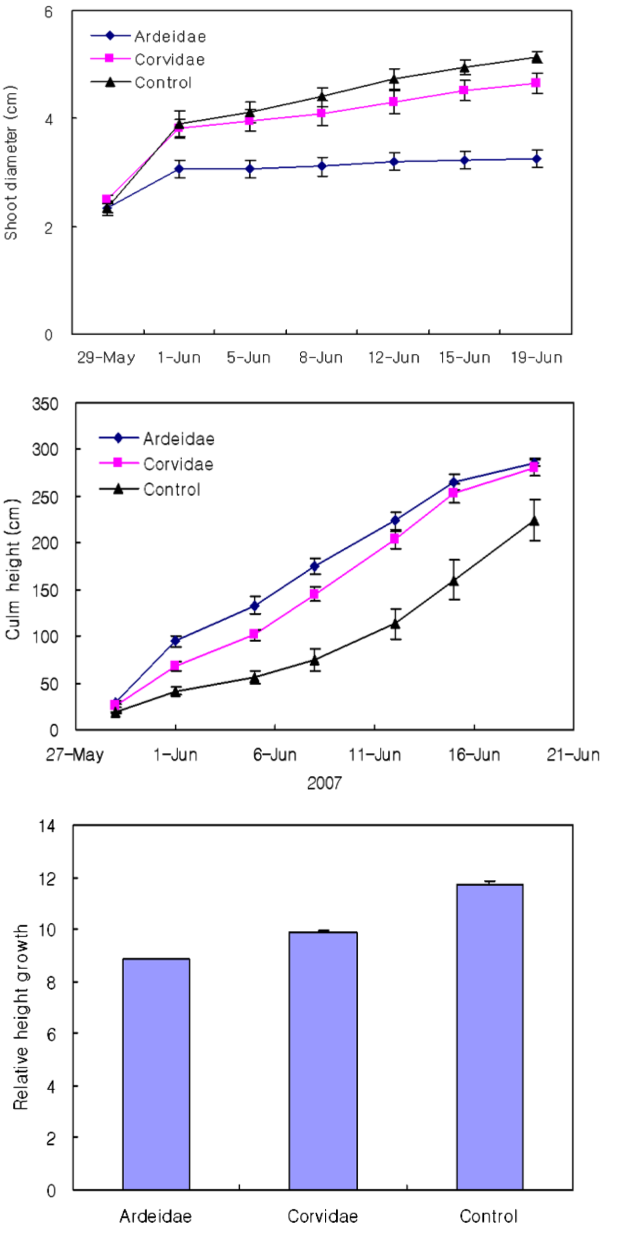

Fig. 8. Shoot growth of newly emerged culms represented as shoot diameter (top), culm height (middle) and relative height growth rate (bottom). Data presented are means ± SE ($n \geq 8$).

Thus, inhabitation of a stand by a large number of ardeids appears to be responsible for the differences in soil and community structure (Lee et al. 2008). In stands occupied by ardeids, a reduction in the soil pH resulted in an increase in the soluble aluminum contents and in turn a reduction in the exchangeable cation contents such as Mg^{2+}, Ca^{2+} and K^{+} (Lee et al. 2007). This is may be due to a reduction in the ability of microorganisms to decompose organic compounds in soil (Kim et al 1998). Increases in concentrations of soluble aluminum in soils resulting from acidification limit root respiration and absorption of cations, especially Mg^{2+} and Ca^{2+}, resulting in retardation of plant growth and eventually plant death (Richter et al. 1992). Thus, soil acidification may be responsible for the density-independent pattern of culm death in the Ardeidae stand. This conclusion was also supported by a study of soil characteristics in the Ardeidae stand (Lee et al. 2007).

In conclusion, the bamboo population in the Ardeidae stand is maintained at large population size by a high rate of new shoot recruitment in spite of a high culm death rate. However, the culm population size and structure in Ardeidae stand is at risk of breaking down because the cause of culm death appears to affect all culms irrespective of culm size. Consequently, a strategy to reduce culm death rates in the Ardeidae stand is needed. On the other hand, in the Corvidae stand, culms smaller than 4 cm DBH had the highest death rates, and most deaths occurred among standing culms suggesting a pattern of density dependent death consistent with self-thinning.

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