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Monitoring Local Populations and Breeding Migration Patterns of the Gold-spotted Pond Frog, *Rana chosenica*

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ABSTRACT: We monitored gold-spotted pond frog (*Rana chosenica*) populations near the Korea National University of Education in Chungbuk, Korea, from 19 May to 8 August, 2006 to examine the spatial distribution of populations in local areas and to investigate patterns of migration of adult gold-spotted pond frogs from terrestrial hibernation sites to breeding sites, We captured individuals from the largest population using a drift fence with 22 pitfall traps surrounding the breeding site. A total of 22 individuals (19 males and 3 females) were captured between 23 May and 15 June. No peak in breeding migration was detected, but the onset of the breeding migration may correspond with increased humidity. Male body weights were negatively correlated with sampling dates. Seven of 22 individuals were captured at the 4th pitfall trap, which was placed between two culverts. The capture rate per pitfall trap was higher in traps close to the rice field banks (1.44, traps 1~9) than in traps facing hilly land (0.33, traps 13~18). Comparative data from the Korean frog (*Rana coreana*), a sympatric species in the study area, were also collected and compared with those of the gold-spotted pond frog.

Key words: Breeding migration, Gold-spotted pond frog, Pitfall trap, Population ecology, *Rana chosenica*, *Rana coreana*

INTRODUCTION

Anthropogenic habitat destruction, modification and fragmentation have been primary causal factors in global amphibian population declines (Alford and Richards 1999, Dodd and Smith 2003). Habitat destruction and degradation not only eliminates the populations directly, but also increases extinction rates of amphibian species by isolating local populations, making them more vulnerable to extinction due to small-population processes.

The gold-spotted pond frog, *Rana chosenica*, is facing the threat of local population extinctions in Korea as a result of human activities. Most gold-spotted pond frog breeding sites are highly fragmented as a result of development and construction of new buildings and roads, cutting of hillsides, and conversion of wetlands for agriculture. Prior to the 1970's, gold-spotted pond frogs were commonly observed in wet areas used for rice cultivation and in marshes and ponds throughout the western and southern Korean Peninsula and on Jeju Island (Won 1971). However, recent surveys showed that the species is rapidly declining in many parts of its original habitat, and has become rare in Jeolla Province and Jeju Island (Lee 2003).

Many conservation efforts have attempted to minimize the loss of amphibian populations by creating biological corridors allowing breeding individuals to migrate between isolated small populations, by providing additional resources for resident individuals, and by translocating individuals into threatened populations (Harris and Scheck 1991, Rosenberg et al. 1997, Gilbert et al. 1998, Kendell 2002). The Korea Government has listed the gold-spotted pond frog as an endangered species since 1975 and the IUCN (The International Union for the Conservation of Nature and Natural Resources) listed it on the 2006 Red List of Threatened Species.

Information about the breeding ecology and behavior of natural populations, such as migration patterns of breeding individuals, is necessary for the development of management plans for gold-spotted pond frog populations. To date, however, few empirical data exist. Thus, research on the structure and dynamics of local populations and short- and long-term population trends is critical for the conservation of the gold-spotted pond frog. In this study, we first examined the distribution of gold-spotted pond frog populations near the Korea National University of Education (KNUE) and estimated the population densities of the frogs in these populations. Second, we collected basic information on the physical characteristics of adult gold-spotted pond frogs and documented the breeding migration patterns of individual frogs in a population. These data were then compared with data from the sympatric species *Rana coreana*. Third, we monitored calls in one population of gold-spotted pond frogs during the breeding season to monitor behavioral aspects

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of breeding such as male-male interactions and female choice. This is the first report about the breeding ecology of the gold-spotted pond frog in Korea, and provides basic information which can be used for conservation of the species and future reintroduction of the species to historical habitats from which it has been extirpated.

MATERIALS AND METHOD

Study Site

The study was conducted from 19 May to 8 August 2006 near the KNUE, Darak Ri, Chungwon Gun, Chungbuk Province, Korea (Fig. 1). We surveyed areas within 2 km of the KNUE for gold-spotted pond frog populations three times over the study period. When a population was found, we estimated the population size using one of two methods: we conducted call surveys by walking slowly along the edge of wet rice fields or ditches at a speed of 100 m per 5 minutes, or employed a mating call playback method (Sung et al. 2005). We chose the largest population identified in preliminary surveys in 2005, population 1, for a study of breeding migration patterns in gold-spotted pond frogs. This frog population lived in a 3,966.3 m^2 wetland area, which was surrounded by a steep 0.3 to 1.2 m bank on three sides (Sections A, B, and D) and faced a low hillside (Section C). The wetland had not been used for rice cultivation for at least six years. We assessed the habitat characteristics in ten 1 m × 1 m sample plots. About 93.8% of the wetland was covered by vegetation, with dominant species including *Bidens tripartite, Persicaria thunbergii, Leersia oryzoides, Bidens frondosa.*

Enclosure Construction and Daily Surveys

A drift fence was set up close to the edge of the wetland to capture migrating breeding frogs. The fence was made of green Formax (60 cm height) with 0.5 cm mesh, and was buried to about 10 cm below the ground surface to prevent frogs from passing under the fence. Twenty-two pitfall traps (diameter 30 cm; depth 45 cm) were placed at 8~10 m intervals on the outer side of the fence. The entrances of the pitfall traps were placed level to the ground to promote frog capture.

We checked the pitfall traps twice per day (10~12 AM; 6~8 PM) except during heavy rain. Adult frogs captured in the traps were considered to be breeding immigrants into the area. We recorded the capture date, time, and location, and measured frog snout-vent length (SVL) to the nearest 0.1 mm and body weight to the nearest 0.1 g. We then clipped the frogs toes for individual recognition and for age determination (Cheong et al 2007), following the toe-clipping guidelines for live amphibians published by the American Society of Ichthyologists and Herpetologists (ASIH) and the Society

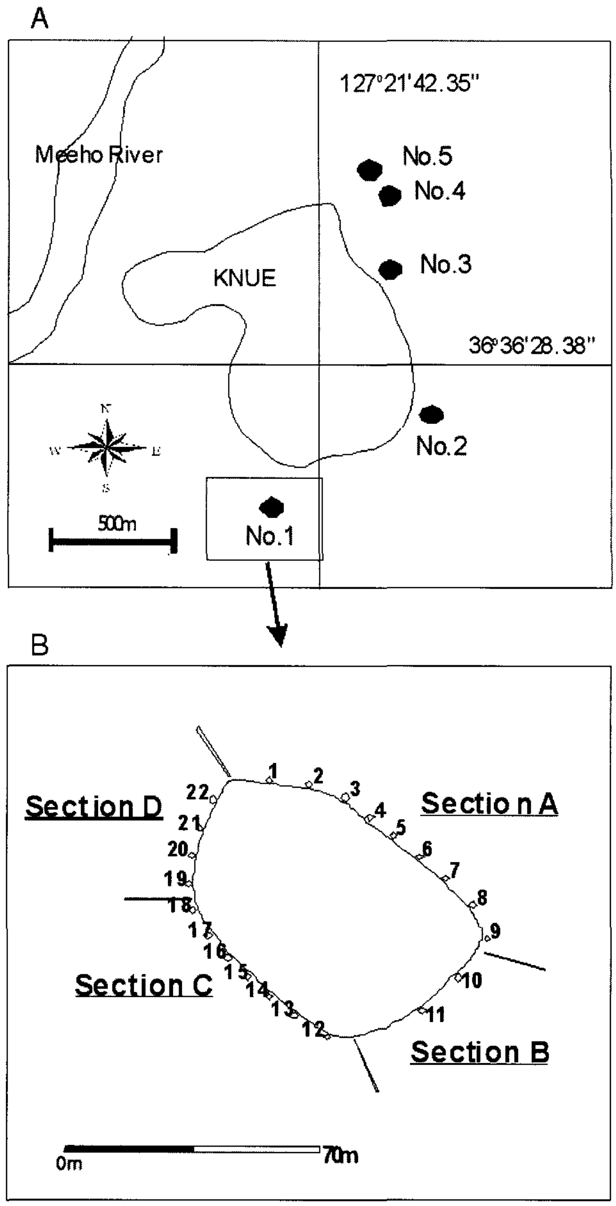

Fig. 1. Study area for call surveys of gold-spotted pond frog (*Rana chosenica*) populations near the Korea National University of Education (A) and the drift fence with pitfall traps used to capture frogs from site 1 (B). Five gold-spotted pond frog populations were identified in this study (sites 1~5). Section A faces high rice field banks, Section B faces another wetland, Section C faces low hillside, and Section D faces a rice field in cultivation.

for the Study of Amphibians and Reptiles (SSAR) (http://www.asih.org/files/hacc-final.pdf). The sex of each frog was determined by the presence or absence of nuptial pads. We then released the captured individuals on the inner side of the fence. To investigate how weather conditions affect breeding migrations, we obtained weather information, including mean daily temperature, humidity, and precipitation for the study period, from reports of the Cheongju Weather Station, which is located about 8 km northwest of the study site.

After checking the pitfall traps, we monitored gold-spotted pond frog calls for five minutes each evening, generally between 19:30 and 20:00. While monitoring frogs, we measured air temperature and humidity with an electric thermometer.

Analysis

To evaluate calling activity of the frogs, we calculated weekly mean calling rates, and compared the mean rate of calling activity across different weather conditions. We used nonparametric statistical tests to analyze the data: we compared average capture rates of gold-spotted pond frogs and Korean frogs across four capture areas using the Chi-square test (Fig. 1), and used Spearman correlation to analyze the relationships between physical characteristics and sampling dates, and between calling activity and weather conditions. Numerical data in the text are presented as mean ± SD.

RESULTS

The Spatial Distribution of Gold-spotted Pond Frog Populations in the Study Area

We confirmed the presence of five gold-spotted pond frog populations near the KNUE during three extensive investigations of the study area in 2006 (Fig. 1). The highest number of individuals was found in site 1, and its population size was estimated as >30 calling individuals. The lowest population, including only one calling frog, was at site 3. The other two sites, sites 2 and 4, were inhabited by 3∼4 calling frogs each. The distance between neighboring populations ranged from 95 m to 550 m. The population estimates in 2006 were similar to those from the preliminarily surveys in 2005. Except for population 1, all population sites were used for rice cultivation, and frog calling started after the sites were flooded for rice-planting.

Patterns of Breeding Migration

A total of 22 adults [3 females (13.6%) and 19 males (86.4%)] were captured while immigrating into a breeding site between 23 May and 15 June, 2006 (Fig. 2A). Females were captured on only two days (two females on 29 May and one on 5 June) in the middle of migration period, and the mean number of individuals/day captured in pitfall traps was relatively low, at 1.10 ± 0.85. No breeding migration peak was detected, but the onset of migration may have corresponded with increased humidity and incidence of precipitation (Fig. 2B, C).

Migration Routes to Breeding Sites

Average capture rates differed significantly among the four capture sections for the gold-spotted pond frog (χ^2=10.23, *df*=3, $p<$ 0.01) and for the Korean frog (*Rana coreana*)(χ^2=15.08, *df*=3, $p<$ 0.001; Fig. 3). The highest capture rate was obtained in section A for both species (gold-spotted pond frog, 1.44; Korean frog, 1.7), and section C had the lowest capture rate for the gold-spotted pond frog (0.33), while section D had the lowest rate for the Korean frog (0.83). As Korean frogs finished breeding, they appeared to mainly use the habitat as feeding grounds. The highest number of individuals was captured in traps 3 and 4, which were placed between two culverts connected to the study site for the outflow of water that was used for rice cultivation.

Physical Characteristics

Females were much larger than males in body weight (female 12.4 ± 1.8 g; male 3.9 ± 1.0 g; Fig. 4A) and SVL (female 43.8 ± 2.9 mm, n=3; male 34.2 ± 2.8 mm, n=19; Fig. 4B), with a 1.28 size ratio of female SVL/male SVL. Male weights were negatively correlated with sampling dates (r_s=−0.53, n=14, p=0.053; Fig. 4C), while SVL were not (r_s=−0.19).

Monitoring Call Activity

We heard an average of 1.66 (± 1.58; range 1∼9) calling individuals per week in the study population. Relatively low numbers of calling frogs were heard throughout the study period and the highest rate of calling activity was detected in the last survey period, from 6 to 8 August (Fig. 2D). No significant relationship was detected between call activity and weather conditions (Fig. 2E, F).

DISCUSSION

This study identified several gold-spotted pond frog populations in the vicinity of the KNUE, where the total breeding population was fragmented into small, isolated local populations, and determined that migration of the frogs may be limited to suitable habitats within a short distance.

Habitat fragmentation and low population densities are two major threats to the conservation of metapopulations of gold-spotted pond frogs (Gotelli 1998, Wilcox and Murphy 1985). Population 1 may function as a source of migrants that could potentially populate new sites in this study area, but the five populations identified in 2006 were isolated from each other by roads or by habitats unsuitable for breeding. In addition, as gold-spotted pond frogs have dispersal ranges of only ∼500 m (Sim 2001), we expect that migration will generally be confined to within small populations, which, in turn, results in reduced population genetic diversity. The habitat

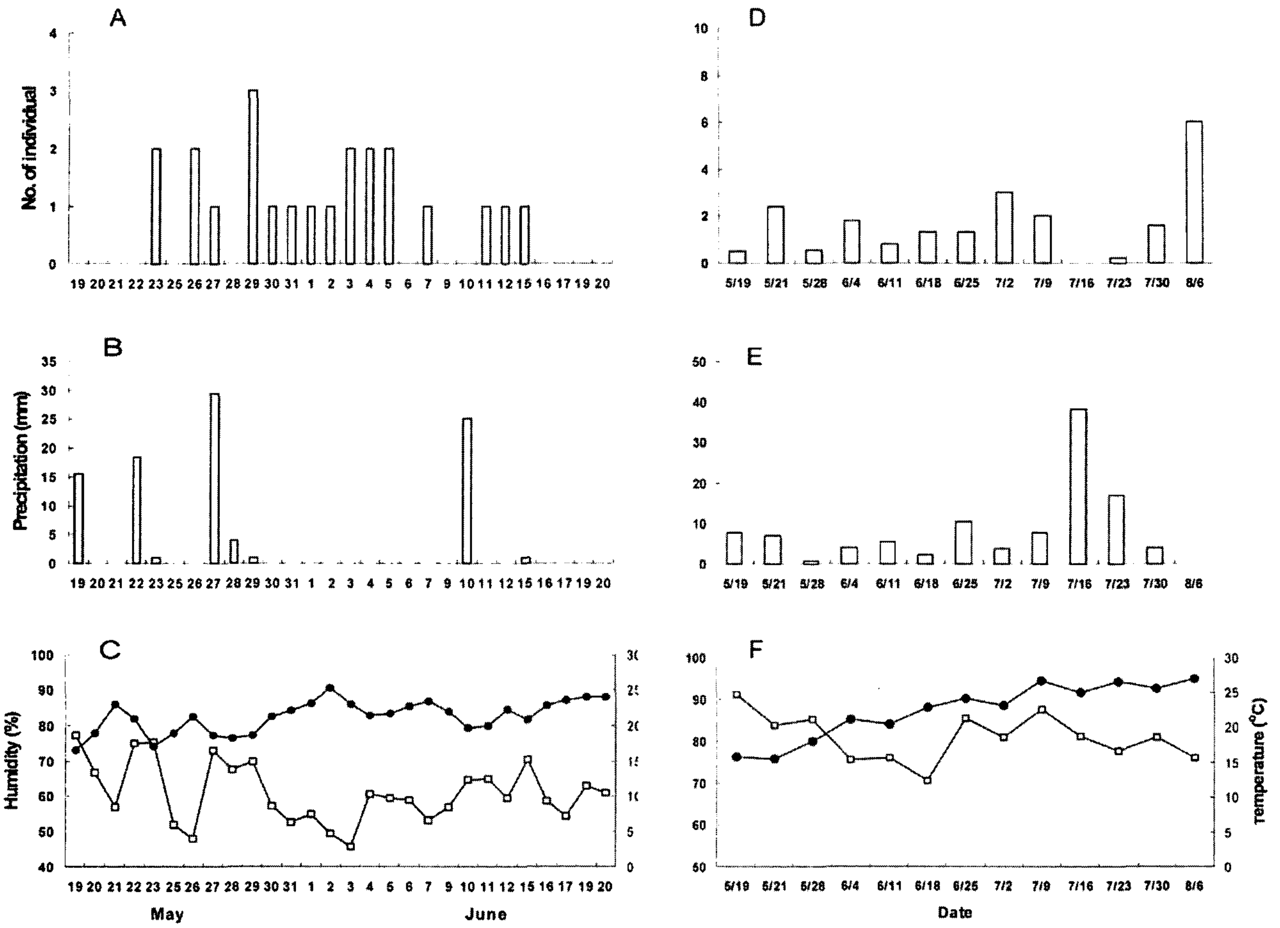

Fig. 2. Number of gold-spotted pond frogs (A) and number of calling individuals (D) in relation to changes in environmental measurements (daily precipitation B, E; air temperature and humidity C, F; □ - humidity, ● - temperature) in population 1 over the study period.

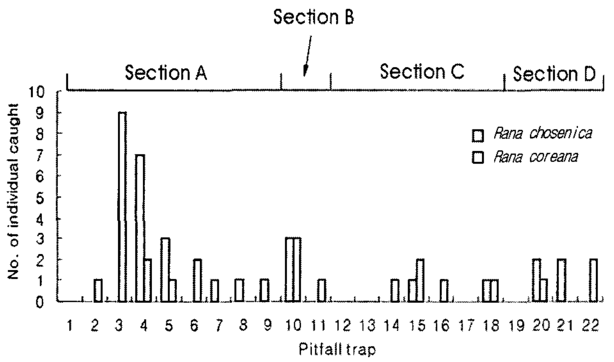

Fig. 3. Number of gold-spotted pond frogs (*Rana chosenica*) and Korean frogs (*Rana coreana*) captured in pitfall traps during the survey period; capture sections are shown in Fig. 1.

of population 1 was filled with earth in 2006 for use in dry-field farming before the frogs emigrated for winter hibernation. In an effort to conserve the population, we transferred 22 adults (19 males; 3 females) and 42 first-year frogs to a pond near population 5 after fitted them with VIE (Visible Implant Elastomer) tags for identification. Despite this intervention, we believe that the gold-spotted pond frog in the KNUE area is at high risk of extinction.

No breeding migration peak, a feature typical of other anuran species, such as Asian toads (*Bufo gargarizans*), was detected. In addition, although population 1 consisted of at least 30 individuals, mating calls were heard at a low frequency throughout the survey period. Low calling activity could be explained in two ways. First, our call monitoring time, 19:00 to 20:00, may have been inappropriate for estimation of overall calling rates, as the diurnal pattern of calling activities showed the highest frequency of calling between 21:00 and 02:00 (unpublished data). Alternatively, as calls are mainly used to attract females and expel other males, the large size of the wetland may have led to low encounter rates among males, reducing the calling rate relative to those of males inhabiting small ponds. The potential for low rates of calling in some gold-spotted pond frog populations may lead to underestimation of population densities during anuran call surveys, which should be considered in

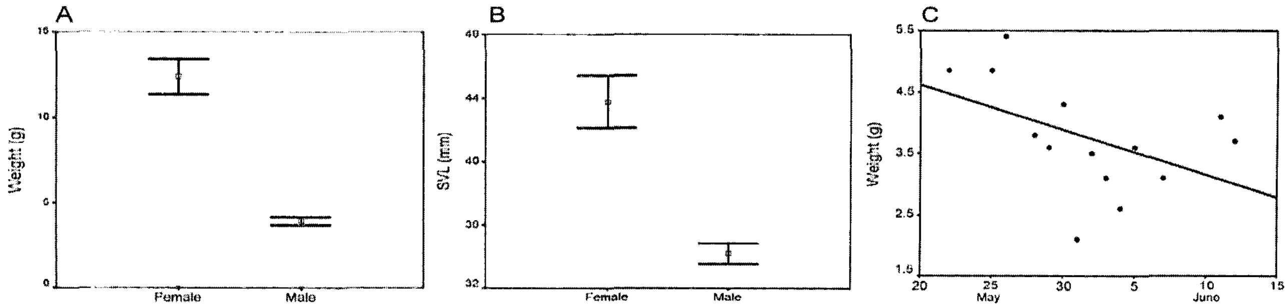

Fig. 4. Sexual size dimorphism in the gold-spotted pond frog: SVL (A), body weight (B) and the relationship between male body weight and sampling dates (C). See text for details.

the future field surveys.

Sexual size dimorphism, which is common in anuran species (Fukuyama and Kusano 1989), was detected in the study population. Shine (1979) reports that females are larger than males in 90% of anuran species, although he did not take the effects of phylogeny into account. Gold-spotted pond frog males in this study were smaller than females and were more abundant at the site. The ratio of female SVL/male SVL at this site (1.28, *N*=3 females, 15 males) was similar to those reported from the north-west coastal area of North Korea (1.20; *N*=20 females, 20 males; Won 1971) and the Chulripo population, Taean-Gun, Chungnam Province (1.55; *N*=4 females, 30 males; unpublished data). Sexual dimorphism in anurans has been described as resulting from the interaction between natural and sexual selection (Lande and Arnold 1983, Ryan 1985, Arak 1988). Arak (1988) showed that sexual dimorphism in body size was related to difference between male and female selection gradients, where males in the lowest reproductive selection gradients relative to females were the smallest. However, it has yet to be conclusively demonstrated that sexual selection is the main cause of size dimorphism in anurans. Recently, Monnet and Cherry (2002) suggested that differences in the age structure of the sexes in breeding populations, rather than sexual selection, may lead to the sexual size dimorphism. Thus, to fully account for the extent of sexual size dimorphism in gold-spotted pond frogs, more attention should be paid to the life-history strategies of the two sexes and the collection of behavioral and ecological data on the selective pressures affecting size dimorphism.

Understanding the pattern of breeding migration in the gold-spotted pond frog may help to develop management plans, as information on summer and winter habitats and breeding ecology is needed. The breeding migration in gold-spotted pond frogs must have begun prior to the date of first capture in this study, because we heard frog calls before setting up the drift fence. Lee (2003) observed gold-spotted pond frogs from April to October in the western coastal area of Sindu-ri, Taean-gun, Chungnam Province. Similarly, Pak et al. (2002) reported frogs coming out of hibernation from the beginning of April in the north-west coastal area of the Korean Peninsula. Unfortunately, the study habitat was destroyed during the course of this study, so we could not obtain more complete information on local ecology and the hibernation period.

The results of this study indicate that gold-spotted pond frogs are facing the risk of extinction in the study populations as a result of low population densities and population isolation, and that protection of breeding sites is critical for the conservation of this endangered species, particularly as they probably use the same sites for breeding and over-wintering. Further studies of the breeding behavior and population ecology of this species are clearly necessary. In areas historically occupied by gold-spotted pond frogs where habitats are badly fragmented or disrupted, more attention should be paid to protection of breeding habitats. Habitat restoration and reintroduction of the frogs should also be carefully considered.

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LITERATURE CITED

Alford RA, Richards SJ. 1999. Global amphibian declines: a problem in applied ecology. Ann Rev Ecol Syst 30: 133-165.

Arak A. 1988. Sexual size dimorphism in body size: a model and a test. Evolution 42: 820-825.

Cheong SK, Park DS, Sung HC, Lee JH, Park SR. 2007. Skeletochronological age determination and comparative demographic analysis of two populations of the Gold-spotted pond frog (*Rana chosenica*). J Ecol Field Biol 30: 57-62.

Dodd CK, Smith LL. 2003. Habitat destruction and alteration: historical trends and future prospects for amphibians. In: Amphibian Conservation (Semlitsch RD ed). Smithsonian Institution, Washington, pp 94-112.

Fukuyama K, Kusano T. 1989. Sexual size dimorphism in a Japanese Stream-breeding frog, *Buergeria buergeri* (Rhacophoridae, Amphibia). In: Proceedings of the Second Japan-China Herpetological Symposium, Kyoto, July 1988 (Matsui M, Hikida T and Goris RC, eds). The Herpetological Society of Japan, Kyoto, pp 306-313.

Gilbert F, Gonzalez A, Evans-Freke I. 1998. Corridors maintain species richness in the fragmented landscapes of a microecosystem. Proc R Soc Lond B 265: 577-592.

Gotelli NJ. 1998. A Primer of Ecology, 2nd edition. Sinauer Associates, Sunderland, MA.

Harris LD, Scheck J. 1991. From implications to applications: the dispersal corridor principle applied to the conservation of biological diversity. In: Nature Conservation 2: the Role of Corridors (Saunders DA, Hobbs RJ, eds). Surrey Beatty & Sons, Chipping Norton, Australia. pp 189-220.

Kendell K. 2002. Northern leopard frog reintroduction: year 4 (2002). Alberta Sustainable Resource Development, Fish and Wildlife Division, Alberta Species at Risk Report No. 78, Edmonton, Alberta.

Pak UI, Kim KC, Kim MS, Kim RT, Kim KN, Kim TS, Rim CY, Han KH. 2002. Red Data Book of DPRK (Animal). MAB National Committee Academy of Sciences, DPRK.

Lande R, Arnold SJ. 1983. The measurement of selection on correlated characters. Evolution 37: 1210-1226.

Lee SC. 2003. Study on *In-situ* and *Ex-situ*, and Restoration Strategy Planning for the Protected Wildlife Anura (*Rana plancyi chosenica* Okada) in Korea (MS thesis). University of Incheon, Incheon.

Monnet JM, Cherry MI. 2002. Sexual size dimorphism in anurans. Proc R Soc Lond B 269: 2301-2307.

Rosenberg DK, Noon BR, Meslow EC. 1997. Biological corridors: Form, function, and efficacy. BioScience 47: 677-688.

Ryan MJ. 1985. The Tungara Frogs: A Study in Sexual Selection and Communication. Univ Chicago Press, Chicago and London.

Shine R. 1979. Sexual selection and sexual dimorphism in the Amphibia. Copeia 1979: 297-306.

Sim JH. 2001. Frogs Calling Life. Darnseisang Press, Seoul.

Sung, HC, Kim SK, Park SR, Park DS. 2005. Effectiveness of mating call playbacks in anuran call monitoring: a case study of three-striped pond frogs (*Rana nigromaculata*). Integ Bios 9: 199-203.

Won HG. 1971. Amphibia and Reptilia in Chosen. The Society of Science, Pyungyang.

Wilcox BA, Murphy DD. 1985. Conservation strategy: the effects of fragmentation on extinction. Am Nat 125: 879-887.

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