



Spatiotemporal distributions and habitat characteristics of the endangered treefrog, *Hyla suweonensis*, in relation to sympatric *H. japonica*



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ABSTRACT

A comparison between localities currently occupied by a species and localities where the species recently underwent local extinction is a powerful way to understand the causes of population decline. Two closely related treefrog species occur in the Republic of Korea: *Hyla japonica*, which is distributed widely throughout northeastern Asia, and *H. suweonensis*, which occurs sympatrically on a narrow strip of the western coastal plains in Korea. Males of both species produce species-specific advertisement calls. To determine the spatiotemporal distributions of *H. suweonensis* and *H. japonica* during their breeding seasons, auditory monitoring was conducted in 70 localities throughout the historic range of *H. suweonensis*. A group of volunteers conducted the monitoring, supplemented with call recordings for validation. The endangered *H. suweonensis* was found in only 14 of 70 localities, designated as syntopic, whereas *H. japonica* occurred in all 70 localities. The calling activity of *H. japonica* was constantly vigorous throughout the study period, whereas the calling activity of *H. suweonensis* was generally weak. The analysis of binary logistic regression identified the percentage of rice-paddy field as the significant variable. The syntopic localities had much higher percentages of the rice-paddy field than the non-syntopic localities did. Localities where the rice-paddy fields are fragmented and isolated by commercial and residential complexes are not likely to harbor the *H. suweonensis* populations. The spatiotemporal distributions of the two treefrog species throughout the breeding seasons confirm that *H. suweonensis* is indeed rare and requires swift and decisive measures, including the establishment of protected areas.

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1. Introduction

Since the early 1990s, the decline of amphibian populations has been recognized on a global scale (Stuart et al., 2004). Due to their permeable skin, life histories involving both aquatic and terrestrial stages (Alford and Richards, 1999; Scribner et al., 2001), and low dispersal ability (Kimberling et al., 1996; Scribner et al., 2001), amphibians are susceptible to multiple factors that are not fully understood yet. Explanations for the decline in amphibian populations include invasive species, overexploitation, habitat modification, atmospheric changes, environmental pollutants, and infectious disease (Collins and Storfer, 2003). However, pinpointing the causes of population decline in amphibian species is one of the most difficult exercises in conservation biology. Single causes are rarely responsible for complete extinction of amphibian species (Blaustein et al., 2011). More commonly, factors acting alone may not be severe, but several factors interacting with each other may be detrimental to amphibian populations (Collins and Storfer, 2003; Hayes

et al., 2010). Furthermore, these causative factors have cascade effects on biological and ecological factors that directly affect death and recruitment of a species (Hayes et al., 2010).

One of the powerful ways to link the causative factors to population decline is to compare localities currently occupied by a species with localities where the species recently underwent local extinction. For example, pond-breeding amphibians are typically modeled within a metapopulation, which is a set of spatially structured local populations whose persistence is a function of local extinction and recolonization (Hanski and Simberloff, 1997). Local disappearance may be caused by deterministic factors, such as destruction of breeding sites and introduction of predatory species, or by stochastic processes such as high rates of local extinction and recolonization (Marsh and Trenham, 2001). When habitat features differ between localities, with recent local extinction and localities currently occupied by a species, deterministic factors are suggested as the primary causes for disappearance of a population. When habitat features are similar across all localities, stochastic processes should be examined first as possible causes of local extinction. Thus, studies about local extinction and colonization, which are inherently challenging to interpret (MacKenzie et al., 2003), can yield important insights, despite confounding effects of multiple anthropogenic and natural processes on population dynamics (Schotthoefner et al., 2011).

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Declines in amphibian populations worldwide call for effective monitoring programs to determine the changes in the distribution and abundance of these species (Pellet and Schmidt, 2005). Various methods such as egg-mass counts, drift fences with pitfall traps, mark–recapture estimates, and calling male counts have been conducted to monitor amphibian populations (Alford and Richards, 1999). Among these methods, call surveys are becoming a standard approach to monitor anuran populations (Bridges et al., 2000). Call surveys have been extensively used by the North American Amphibian Monitoring Program (NAAMP) (Mossman et al., 1998), which was established in 1994 to monitor the standard distribution and abundance of amphibian populations in the United States and Canada. This protocol is based on a volunteer-based auditory survey during the breeding season. The method relies on the distinguishing anuran advertisement calls only, and is easy and inexpensive (Corn et al., 2000). In addition, if many volunteers are secured, monitoring can cover a wide range of areas (Heyer et al., 1994).

Although the NAAMP call survey has been successfully used across diverse taxa of frogs (Crouch and Paton, 2002; Pillsbury and Miller, 2008; Weir et al., 2005), this method exhibits several potential problems. First, the call survey protocols fail to detect the occurrence of all anuran species (Bridges et al., 2000; Corn et al., 2000). Specifically, rare and infrequently calling species are easily overlooked (Corn et al., 2000). Second, misidentification of anuran calls by inadequately trained volunteers can generate invalid data (Bridges et al., 2000). To remedy these drawbacks, intensive and localized survey efforts are required to monitor rare and endangered species (Crouch and Paton, 2002). Furthermore, data obtained by volunteers should be supported by recordings of advertisement calls for identification.

Two treefrog species occur in the Republic of Korea: *Hyla suweonensis* and *H. japonica*. While *H. japonica* is distributed widely, *H. suweonensis* is restricted to the west coastal plains (Kuramoto, 1980; Yang et al., 1997). *H. suweonensis* has been listed as a Data Deficient Species on the IUCN Red List of Threatened Species since 2004 and was designated as endangered by the Korean government in 2012 (Ministry of Environment of Korea, 2012). These two species typically breed from May to late July in places with standing water, such as rice paddies and wetlands. The two species are separated by 15.66% genetic differentiation on the mitochondrial cytochrome *b* gene and 7.17% on the mitochondrial 12S RNA gene (Lee et al., 1999; Yang et al., 1997). A more pronounced angle at the prolongation of the lateral line between eyes and snout makes the males of *H. japonica* broader and stouter than the males of *H. suweonensis* (Borzée et al., 2013).

Advertisement calls of treefrogs are one of the most dominant soundscapes in rural areas during the treefrog breeding seasons in Korea. The advertisement calls of *H. suweonensis* and *H. japonica* are species-specific. The two treefrogs species call continuously, several hours per night, in a predictable manner (Jang et al., 2011; Kim et al., 2012a; Yoo and Jang, 2011). The calls of *H. suweonensis* are generally lower in note repetition rate and higher in dominant frequency than those of *H. japonica* (Park et al., 2013). In this study, we investigated the spatiotemporal distributions of the endangered *H. suweonensis* in relation to the sympatric *H. japonica*, using auditory monitoring. This study was conducted with the aid of volunteers who monitored the two *Hyla* species throughout sympatric areas during the 9-week study period. We determined the land cover factors that were critical for occurrence and abundance of *H. suweonensis* using a geographic information system (GIS) analysis.

In addition, we tried to infer the possible causes of population decline in *H. suweonensis* by testing predictions of deterministic and stochastic factors. When a deterministic factor is responsible for population decline, localities currently occupied by *H. suweonensis* may be different from localities that may have undergone local extinction. When a stochastic factor underlies the population decline, localities may all be similar to each other, in terms of abiotic and biotic causes of population decline, regardless of the presence of *H. suweonensis*.

2. Methods

2.1. Study localities

The historic distributional range of *H. suweonensis* covered most of Gyeonggi Province, the north of Chungcheongnam Province, and the northwest of Chungcheongbuk Province (Yang, 2000). The sampling area (latitude 36.15–37.95°N; longitude 126.0–127.8°E) for this study included the historic range of *H. suweonensis* (Fig. 1). However, the sampling area extended south to include most of Chungcheongnam Province because the southern distributional limit of *H. suweonensis* was unknown at the time. We relied on random sampling to unbiasedly select localities for acoustic monitoring (Dorcas et al., 2009). Within this rectangular sampling area, we randomly generated latitudes and longitudes for roadside localities (Lannoo, 2005). If appropriate roads did not exist near the selected locality, another locality was randomly selected. These localities were restricted to rice paddies in which rice seedlings grew during our study period. Natural wetlands where treefrogs occur are extremely rare in the Republic of Korea, and most treefrogs breed in rice paddies (Yang, 2000).

Of the 200 randomly-generated localities, we let a group of volunteers choose their preferred localities. In addition to random sampling, seven localities where *H. suweonensis* was known to occur were added for auditory monitoring. This was necessary because random sampling may not have included enough localities where *H. suweonensis*

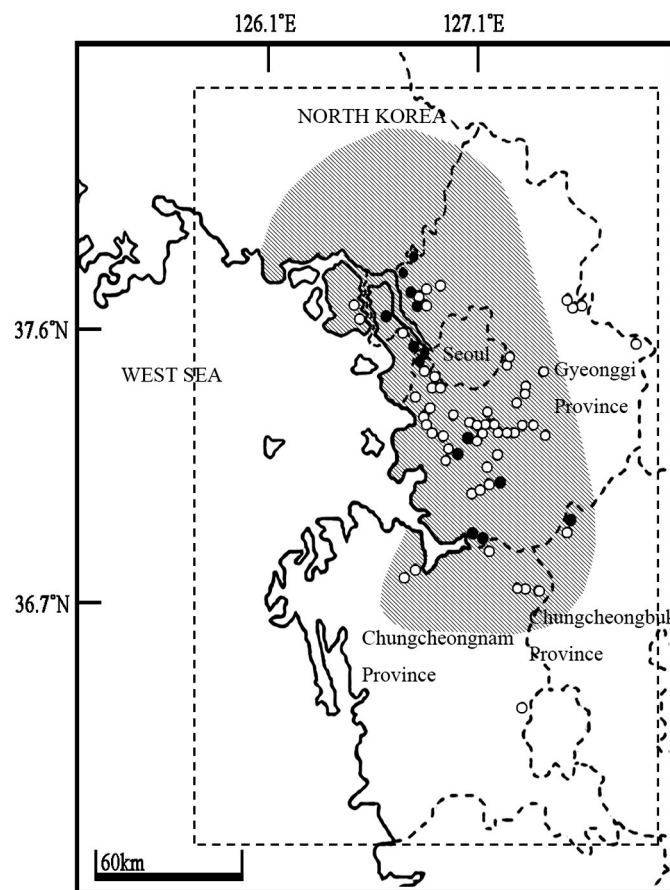


Fig. 1. Auditory monitoring sampling localities to determine the spatiotemporal distributions of *Hyla suweonensis* and *H. japonica*. The shaded area was the historic distributional range of *H. suweonensis*, and the rectangular area was the sampling area for this study. We randomly generated localities within the rectangular area (lat. 36.15–37.95°N; long. 126.0–127.8°E) and volunteers chose localities for auditory monitoring. Seventy localities were sampled for auditory monitoring. Solid dots are the localities where *H. suweonensis* and *H. japonica* were found, and white dots are the localities where only *H. japonica* was found. *H. suweonensis* was never found alone at a locality.

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