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POLICY BRIEF
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Policy Recommendation for the Conservation of the Suweon Treefrog (*Dryophytes suweonensis*) in the Republic of Korea

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The Suweon treefrog (*Dryophytes suweonensis*) is an endangered species with an important evolutionary significance. However, the current rate of decline projects the extinction of the species within a few decades in the Republic of Korea. The species is presently exclusively inhabiting rice paddies and is not present in any protected area, although it would be relatively easy to designate protected area under the RAMSAR convention and correct the current negative population dynamics. Through three policy recommendations, we present the points of importance for the conservation of the Suweon Treefrog, list the site of importance for its conservation, and introduce an agricultural model allowing for the conservation of the species as well as continued rice production and economic income.

Actionable recommendations:

- Establishment of protected areas within the range of *D. suweonensis*
- Pesticide and herbicide ban in rice-paddy complexes where *D. suweonensis* occurs
- Vegetation mowing limit for surroundings of rice paddies where *D. suweonensis* occurs.

Keywords: conservation, policy, Suweon Treefrog, Republic of Korea, *Dryophytes suweonensis*

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INTRODUCTION

The Suweon Treefrog (*Dryophytes [Hyla] suweonensis*; Duellman et al., 2016) is an endangered species in the Republic of Korea (IUCN, 2018) due to a low extent of occurrence (Borzée et al., 2017a), fragmented population (Borzée, 2018) and continuing decline in area of occurrence (Borzée et al., 2018a). About 2,500 calling males are estimated to be present in the Republic of Korea (Borzée et al., 2018a), segregated into 14 disconnected areas (Borzée, 2018). The species is also known to occur at a minimum of three sites in the Democratic People's Republic of Korea, with at least one seemingly healthy sub-population (Chun et al., 2012; Borzée and Seliger, 2018); although population sizes are not available for the country. Under the current threat levels, the species could become extinct within decades (Borzée, 2018).

In the Republic of Korea the species ranges from the Mangyeong River in the south to the Imjin River in the north (Kim et al., 2012; Borzée et al., 2016c, 2017a). Population sizes are generally decreasing because of habitat loss through encroachment and urbanization (Lee and Miller-Rushing, 2014), although some rare populations displayed low increases between 2015 and 2017 (Borzée et al., 2018a). Despite landscape modifications being the first reason for the endangered status of *D. suweonensis* (Borzée and Jang, 2015; Borzée, 2018),

the species is under multiple threats including hybridization (Kuramoto, 1984; Borzée and Jang, 2018b), competition with *D. japonicus* (Borzée et al., 2016a,b, 2018e; Borzée and Jang, 2018a), environmental pollution (Borzée et al., 2018d), crop management and harvest (Borzée and Jang, 2017; Borzée et al., 2018b), emergent diseases such as the Chytrid fundus (Borzée et al., 2017b), and invasive species (Kim, 2016; Borzée et al., 2017b), among the main and defined threats.

It is important to protect the species due to its clear evolutionary potential, differentiated from other Hylid species by a switch in heterogamety resulting in a ZW system (Dufresnes et al., 2015), and in regard to the international conservation crisis involving amphibians worldwide (Stuart et al., 2004; Beebee and Griffiths, 2005; Bishop et al., 2012; Wake, 2012; Howard and Bickford, 2014; Pimm et al., 2014). Despite the current situation, *D. suweonensis* is not present in any protected area (Borzée et al., 2017a) and is only known to breed in rice paddies (Borzée and Jang, 2015), while original potential habitats might have included wetlands with low vegetation including *Alopecurus* sp. and *Typha* spp. (Borzée and Jang, 2015). The only conservation project to reintroduce the species was unsuccessful (Borzée et al., 2018c) and despite plans for *ex-situ* breeding facilities having been drafted (Noh, 2017), conservation of populations in the wild would simplify the protection of the species (Snyder et al., 1996). Additionally, the species (Borzée et al., 2018b) and other anuran species can adequately take advantage of the artificial flooding of rice paddies for agricultural purposes (Fujioka and Lane, 1997; Machado and Maltchik, 2010; Naito et al., 2013; Holzer, 2014; Orchard et al., 2019).

Amphibian conservation plans benefit from articulating local policies around the prioritized actions of the Amphibian Conservation Action Plan (Wren et al., 2015). Out of the 12 chapters of the ACAP, some sections on habitat protection and ecotoxicology are relevant to the policy recommendations recommended here. Regarding habitat protection, the ACAP recommends first to refine the definition of "Critical Habitat" for the target species and develop a list of standards for the identification of important sites. In the long term, the ACAP recommends developing "Amphibian Critical Habitat" keys to identify priority sites. Regarding ecotoxicology, short term recommendations include identifying organic agriculture movements to explore potential development and working with authorities to change legislation. They also include developing outreach material on the effects of locally applied pollutants on amphibian and human health at the stakeholder level, here rice farmers. Long term recommendations include long-term partnerships with organic agriculture organizations and the social marketing of the issue through the establishment of links with grassroots organizations. The policy recommendations made here are in-line with these global recommendations.

POLICY AND PRACTICE

Consequently, we recommend three policies for the *in-situ* conservation of the Suweon Treefrog (*D. suweonensis)*. These policies are independent of each other and need not be implemented in the order presented here.

Designation of Protected Areas Within the Range of the Species

We strongly urge the preservation of the current rice paddy system and the continued agricultural practices by farmers such as current timing of flooding, tilling and planting (Borzée et al., 2018b). However, avoiding burning straws left-over from the harvest before the fallow phase would avoid lethal consequences to individuals brumating in the vicinity of the rice paddies (Borzée et al., 2019). The designation of agricultural wetlands as protected area and their continued harvest may be conducted under the guidelines stipulated in the RAMSAR convention (see Classification of Wetland Type, §4.3.4; Ramsar Convention Secretariat, 2013) and governmental funding following those provided for "agri-environment" support programmes in the UK, where funding is matched to a score based on defined environmental benefits (Baker et al., 2011). This recommendation is based on the fact that the breeding activity of *D. suweonensis* is synchronized with the regulated hydroperiod resulting from the flooding of rice paddies for rice cultivation (Borzée et al., 2018b), which has so far resulted in adequate population recruitment. The transformation of rice paddies into natural wetlands is not recommended at the moment as the data available on the natural requirements of the species are still limited and transformations may result in the local extirpation of the species if conducted inadequately. The knowledge currently available only includes partial vegetation data, habitat size, and distribution models (Borzée and Jang, 2015; Song, 2015; Borzée et al., 2017a). In this regard, we recommend the implementation of protected area at the sites of Sihung, Iksan, Paju, Asan, and Chungju based on genetic variability (Borzée et al., 2018c; **Figure 1**), large source populations, buffer populations and important populations for connectivity (Borzée, 2018).

Habitat Protection

We recommend the ban of pesticides and herbicides in the rice-paddy complexes where *D. suweonensis* is known to occur (Borzée et al., 2017a; **Figure 1**), as these are related to lower population sizes (Borzée et al., 2018d). The chemicals to be avoided are the ones resulting in high levels of phosphates and nitrates in the environment, and their application should be avoided during the breeding season (May and June) and tadpole development (June and July). We recommend a shift to ecological agriculture, a demonstrated way to maintain sustainability (Bellon and Penvern, 2014), including for rice harvest (Mendoza, 2008; Lestari and Suryana, 2013), as recommended by the government of the Republic of Korea (Jeong and Moon, 2013; Ministry of Agriculture Food and Rural Affairs, 2013) and already locally demonstrated (Lee et al., 2016). This would enable the conservation of the *D. suweonensis* in rice agricultural landscapes. We recommend the policy shift to be acknowledged by a special "Suweon Treefrog friendly" label, which would be economically sustainable (Jaďudová et al., 2018) and in line with the rising environment and conservation awareness worldwide

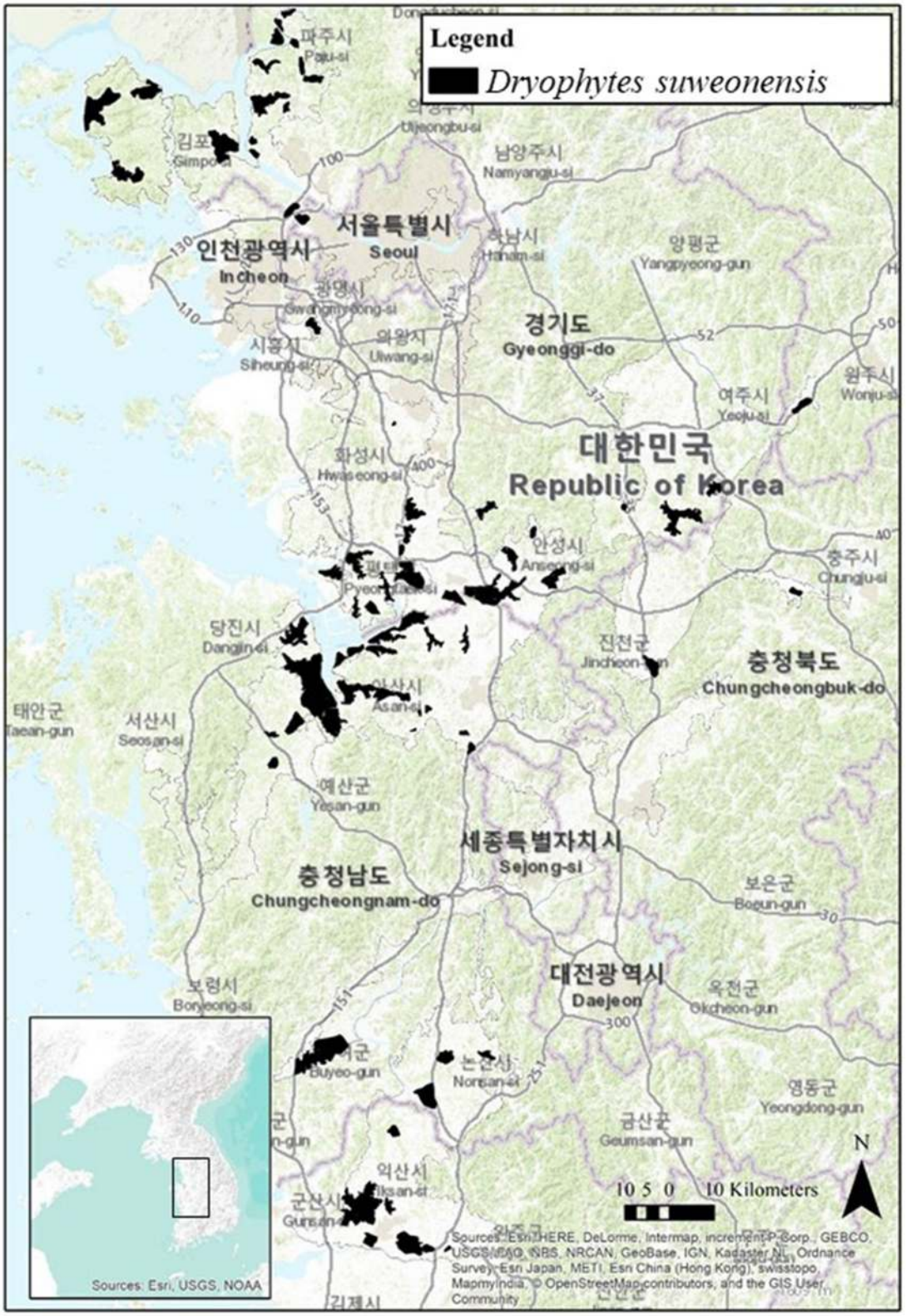

FIGURE 1 | Distribution of *Dryophytes suweonensis* in the Republic of Korea. Each black patch represents an area within which sites where the species is present are connected (Borzée et al., 2018a), but disconnected from the nearest rice-paddy complex (Borzée, 2018). The species range is extracted from Borzée et al. (2017a). Map generated through ArcMap 10.5 (Environmental Systems Resource Institute, Redlands, California, USA).

(Sutherland et al., 2018). This is the case of "Gangwha Maewha-malleum rice," set up to protect the endangered *Ranunculus kazusensis makino* in a Ramsar site composed of rice paddies only and managed by the Korea National Trust Foundation (Ramsar Convention, 2018).

Microhabitat Management

Finally, we recommend a limit in the cutting of grass surrounding rice paddies at all sites where *D. suweonensis* occurs. Mowing grass present on ditches and delimitation banks between rice paddies is negatively impacting the species, as this environment is the preferred diurnal resting habitat (Borzée et al., 2016a; Groffen et al., 2018) and is also used for feeding, microhabitat segregation with *D. japonicus* and overwintering (Borzée et al., 2016a, 2019). We acknowledge the need for weed control and shade prevention for rice growth, and when the vegetation needs to be cut, it should not be done below 30 cm as frogs diurnal activity is below this height (Borzée et al., 2016a), and as this is unlikely to impact rice production due to a lower height than the rice itself. When possible, vegetation including Korean willows (*Salix koreensis*), and occasionally high grasses such as *Elymus repens* and *Phragmites communis* should be maintained in the vicinity of rice paddies to allow for population connectivity (Driscoll et al., 2013; Schneider-Maunoury et al., 2016), as well as foraging and overwintering by *D. suweonensis* (Borzée et al., 2016a, 2019).

The implementation of these policies will enable the survival of the Suweon treefrog (*D. suweonensis*) and the continued production of rice, highlighting the importance of the Republic of Korea in biological conservation and organic sustainable development. Moreover, our recommendations are based on a review of the literature presenting such cases and can be adapted to protect any species relying on rice paddies during their life cycle.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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