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RESEARCH ARTICLE

IMPACT OF RICE AND BEAN HARVESTS ON THE SUWEON TREEFROG (*DRYOPHYTES SUWEONENSIS*)

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ABSTRACT

Numerous amphibian species are currently restricted to breeding in agricultural landscapes, although the impact of agricultural techniques, such as harvesting, are not yet determined. In the Republic of Korea, the Suweon Treefrog (*Dryophytes suweonensis*) is restricted to breeding in rice paddies. In fall, numerous individuals are found on cultivated bean plants, on the edges of rice paddies. In this study, we conducted repeated surveys at four sites during the brumation period, from late September to the first freeze, to determine the relation between the abundance of individuals and harvests of bean and rice crops. We found that the rice and bean harvests had a significant negative effect on the number of adults present at sites, while it only was a trends for juveniles. We consequently recommend the delay of rice and bean harvests until after the first freeze at site where *D. suweonensis* occurs.

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INTRODUCTION

The direct impact of crop harvests on animal communities is clearly negative, although it is difficult to assess their exact effects (Humbert *et al*, 2009). A type of harvest with a demonstrated negative impact on amphibians is timber (Petranka, 1994; Semlitsch *et al*, 2009). Theimpact of crop harvests, such as rice, on amphibian communities has not been clearly demonstrated so far. Despite this unknown, rice paddies are substitute habitats to numerous anuran species in both America and Eurasia (Hobbs *et al*, 2009; Machado and Maltchik, 2010; Fujioka and Lane, 1997; Magle *et al*, 2012; Naito *et al*, 2013; Holzer, 2014; Borzée and Jang, 2015). One of the counterpoints of the impact of rice paddy harvests is the prolonged yearly hydroperiod and decreased accessibility by predators. This may facilitate the use of this human-modified habitat by amphibians.Rice paddies in the Republic of Korea have totally replaced the natural habitat of the Suweon treefrog, *Dryophytes suweonensis* (Borzée and Jang, 2015). They are typically arranged in rice-paddy complexes, clustered in a geometric patterns along a central ditch used for irrigation. This ditch is usually bordered by a row of planted beans. At sites where *D. suweonensis* occurs (Borzée *et al*, 2016c; Borzée *et al*, 2017a), a large number of individuals are sitting on the leave of the bean plants during brumation, from sunset until late at night. The frogs are still present in this habitat when rice and beans are harvested. This may create yet another environmental pressure on the endangered *D. suweonensis*. The causes of decline for the species are multiple and include habitat destruction (Borzée *et al*, 2015; Borzée *et al*, 2017a), competition with other treefrog species (Borzée *et al*, 2016b; Borzée *et al*, 2016a) and emerging diseases in relation to invasive species (Borzée *et al*, 2017b). Here, we hypothesise that the harvest of bean and rice crops has a negative impact on the number of individuals along rice paddies.

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MATERIALS AND METHODS

Field surveys

Observations of the brumation ecology of *D. suweonensis* in the field were collected at four localities in 2015 (Fig. 1). Each localities was within arice-paddy complex, selected following observations of calling males produced by both *Dryophytes* species during the breeding season (see Borzée and Jang, 2015; Roh *et al*, 2014). All sites were surveyed on 16 September 2015, on 1 and 15 October 2015 and on 4 November 2015. The presence of individuals was assessed through spotlight transects (Smith and Nydegger, 1985), where the researcher follows a pre-determined 250-m long transect and visually inspects the vegetation for individuals. All transects were conducted in rice-paddy complexes, along the cemented path running at the centre of the complexes for irrigation purposes. Surveys were conducted between sunset and 10 pm. All individuals found were hand caught and the species was identified based on morphology (Borzée *et al*, 2013). For each survey, we counted the number of adult and juvenile *D. suweonensis*, as well as the harvest advancement of the rice and bean crops along the transects. As surveys were conducted with at least a week interval, and because harvests for a type of crop are within a short time window, all the rice paddies along a transect went from non-harvested to harvested between two surveys. All observations were conducted with the agreement of the Ministry of Environment from the Republic of Korea, under the permits numbers: 2015-3, 2015-4, 2015-6 and 2015-28.

Statistical analyses

The analysis conducted here aimed at determining the impact of rice and bean harvests on the occurrence of *D. suweonensis*. Harvests for each crop were binary encoded for harvested or non-harvested. We used the harvest advancement for both rice and bean crops as dependent variables in a multivariate General Linear Model to assess the impacts of harvest on the number of both juveniles and adults, which were set as covariates. The analysis was ran under a main effect model for the covariates. The number of adults and juveniles were not correlated (Pearson correlation; $r = 0.13$, $n = 16$, $p > 0.05$).

To determine if the test selected was not violating assumptions, we visually tested for the absence of outliers through the analysis of box-plots, and we determined the normal distribution of residuals through the analysis of the normal Q-Q Plots. From the graph, we concluded that the data appeared to be normally distributed and did not display a non-linear pattern. We also determined the homogeneity of variance with Levene's test for homogeneity of variances (*D. suweonensis* adults: $F_{(2,16)} = 5.97$, $p > 0.05$; *D. suweonensis* juveniles: $F_{(2,16)} = 11.96$, $p > 0.05$). We did not include the variable season and temperature as they were correlated with the occurrence of the species (Pearson correlation; $n = 16$; with juveniles: $r < 0.37$, $p < 0.003$; with adults: $r < 0.34$, $p < 0.007$). We therefore acknowledge that subsequent analyses of this dataset are under the influence of the confounding factors season and temperature. Testing for the factors season and rice harvest in relation to the occurrence of *D. suweonensis* would require farmers not to harvest rice.All analyses were conducted in SPSS (IBM SPSS Statistics Inc., Chicago USA).

RESULTS

When looking at the number of individual *Dryophytes suweonensis* in relation with the rice harvest, the average number of adult was higher (2.38 ± 1.32; mean ± SD; range from 0 to 4 individuals) for non-harvested sites than for harvested sites (0.86 ± 1.02; range 0 - 3). The difference was more important for juveniles, with on average 16.00 ±22.24 individuals at non-harvested sites (range 0 - 61), and 1.36 ± 1.86 individuals at harvested sites (range 0 - 6; Fig. 2). The pattern was the same for the bean harvest, with on average 2.16 ± 1.25 adults at non-harvested sites (range 0 - 4) and 0.25 ± 0.46 adults at harvested sites (range 0 – 1), and a larger difference between juveniles, with on average 11.79 ± 19. 27 juveniles at non-harvested sites (range 0 - 61) and 0.38 ± 1.06 individuals at harvested sites (range 0 – 3; Fig. 3). The analysis for the variation in number of individuals before and after harvests was only significant for adult *D. suweonensis*, in relation to the harvest of both bean and rice crops (Table 1). However, a non-significant trend was visible for juveniles in relation to both harvests.

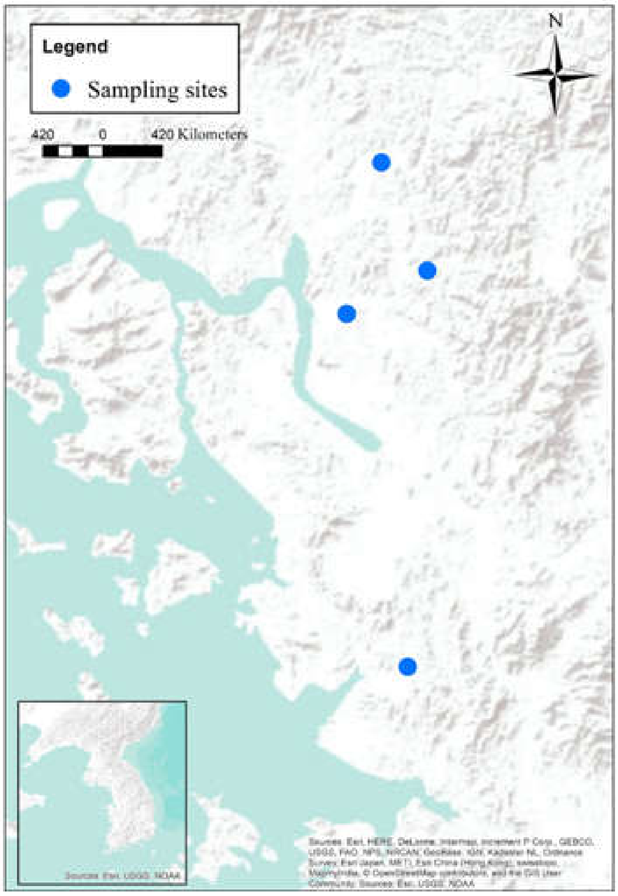

Figure 1. Sampling sites to assess the impact of bean and rice harvest on the number of adult and juveniles *Dryophytes suweonensis*. Surveys were conducted in fall 2015.This map was generated with ArcMap 9.3 (Environmental Systems Resource Institute, Redlands, California, USA; http://www.esri.com/)

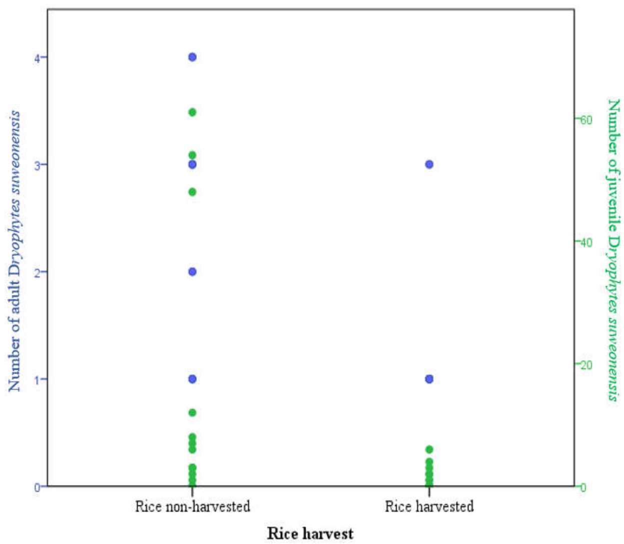

Figure 2. Number of adult and juvenile *Dryophytes suweonensis* in relation with the rice harvest along the central ditch running through rice-paddy complexes during the brumation period in 2015

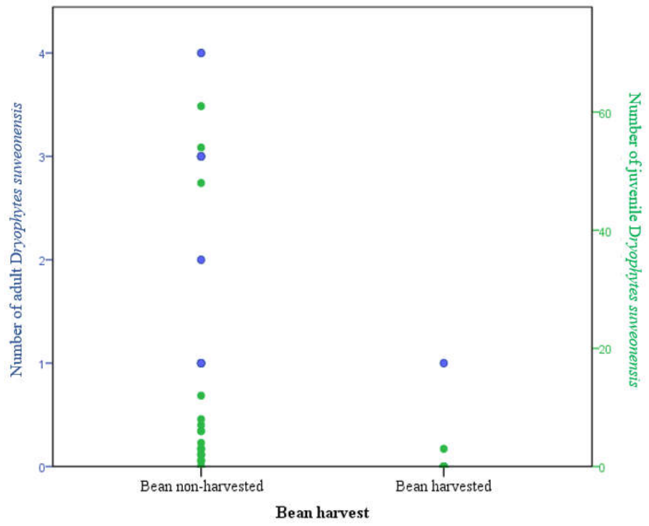

Figure 3. Number of adult and juvenile *Dryophytes suweonensis* in relation with the bean harvest along the central ditch running through rice-paddy complexes during the brumation period in 2015

Table 1. Results of the GLM testing for the effect of rice and bean harvests on the number of juvenile and adult *Dryophytes suweonensis* at four sites close to Seoul, in the Republic of Korea. Surveys were conducted during the brumation season 2015

Dryophytes suweonensis	Harvest	χ^2	*df*	*F*	*p*-value
Adults	Rice	0.82	1	4.26	0.050
	Bean	1.93	1	14.68	0.001
Juveniles	Rice	0.03	1	0.17	0.687
	Bean	0.20	1	1.51	0.231
Error	Rice	4.61	16		
	Bean	3.15	16		

DISCUSSION

Adult and juvenile *Dryophytes suweonensis* were found in the vicinity of rice paddies during the brumation period, favouring the upper leaves of planted beans. This is however making the species susceptible to both bean and rice harvests, which resulted in a significant drop of adult *D. suweonensis* at the sites. This may have an impact on the recruitment of young individuals into the breeding pool, as adults will not be able to able to breed the subsequent year. Besides, individuals usually shelter underground during hibernation, on the banks of rice paddies, where rice straws are stacked after harvest, but also burnt before the thaw of ice, with unknown consequences on the species. Despite not being significant, the same trend was found for juveniles in relation to both harvests, where a lower number of *D. suweonensis* was found after the harvests. We suspect that individuals died during the harvest, although it is unlikely but possible that the individuals were not observed because of the removal of the preferred substrate. Thus, based on the significant results, we recommend the delay of the bean and rice harvests until after the first freeze at sites where *D. suweonensis* is present. The loss of this evolutionary significant species (Dufresnes *et al*, 2015) would be a major negative impact on Korean biodiversity.

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