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КРАТКИЕ СООБЩЕНИЯ

INTERFERENCE COMPETITION DRIVEN BY HYDRIC STRESS IN KOREAN HYLIDS

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Competition is based on the type and importance of the resource sought, and interactions intensify with the importance of a given resource. One of the highest degrees of interference competition is physical interactions for a given resource. The treefrogs *Dryophytes japonicus* and *D. suweonensis* compete for spatial resources for the production of advertisement calls. Here, we have investigated a case of direct interference competition due to artificial hydric stress caused by variations in the irrigation system of rice paddies. Under this specific condition, an unusually high number of males of both species congregated in a single flooded field. We first found that males segregated following a demonstrated pattern, with *D. japonicus* on the edges and *D. suweonensis* at the centre of the submerged field. However, the differences in the distance to the edge of the submerged field for amplexuses of the two species were not significantly different. Due to the high number of individuals and the small size of the site, the area used by males of both species partly overlapped, and thus lead to physical interactions between two males of the two species. *Dryophytes japonicus* took over a calling site and managed to remove the opponent male. We sequentially described the interaction here, potentially representative of the general outcome of interference competition between these two species.

Key words: *Dryophytes japonicus*, *Dryophytes suweonensis*, interference competition, Korean Hylids, physical fight

Introduction

All organisms need resources and often these are in short supply, thus resulting in competition (Schluter, 2000). Although attenuated by speciali-sation and niche selection (Turelli et al., 2001), competition may lead to divergences over time (Lack, 1947; Schluter, 2000), and possibly specia-tion such as in Darwin's finches (Grant & Grant, 2002). Competition can be further dichotomised between exploitative and interference competition. For instance, intraspecific interference competition in *Rana utricularia* Harlan, 1826 tadpoles sup-planted exploitative competition (Steinwascher, 1978), and intraspecific visual interference com-petition played a role in larval development in *R. kukunoris* Nikolsky, 1918 (Yu & Lambert, 2015). However, the two types of competition are non-mutually exclusive, as seen between *Ambystoma talpoideum* (Holbrook, 1838) and *A. maculatum* (Shaw, 1802) (Walls & Jaeger, 1987) and between *Rana temporaria* Linnaeus, 1758 and *Bufo calami-ta* Laurenti, 1768 (Griffiths et al., 1991).

Interference competition between species occurs both directly and indirectly. An example of direct competition is between the larvae of the salamander *Ambystoma maculatum* and *A. tal-poideum,* competing over hides (Walls, 1990). An examples of indirect interference competi-tion is the production of growth inhibition chem-icals by the tadpoles of *Bufo calamita* and *Rana temporaria* (Beebee, 1991). However, because of variations in species abilities to exploit re-sources, the impact of competition can be either symmetric or asymmetric (Begon et al., 2006). For instance, when in sympatry with *Rana blairi* (Mecham, Littlejohn, Oldham, Brown & Brown, 1973), the length of the larval period will in-crease and the metamorphic body mass will decrease in *R. areolata* Baird & Girard, 1852, while *R. blairi* will experience a drop in the number of metamorphosing individuals (Parris & Semlitsch, 1998).

On the Korean Peninsula, *Dryophytes japoni-cus* (Günther, 1859) and *D. suweonensis* (Kura-

moto, 1980) (previously *Hyla*; Duellman et al., 2016), are competing with each other for calling space in rice paddies. The calling space used by *D. suweonensis* is limited by the calling activity of *D. japonicus*, but not vice-versa (Kim, 2015; Borzée et al., 2016a,b). Here, we report the first case of interference competition between these two treefrog species. Physical encounter between calling males of the two species does not usually occurs due to habitat segregation (Borzée et al., 2016a), following historical differential use of the environment (Kim, 2016; Borzée et al., 2017). However, in this special case of human-induced hydric stress, the two species were brought in physical contact.

Material and Methods

This abnormal situation of hydric stress during the peak breeding season was observed on 27 June 2015 at 20:25 p.m. in Chungju, Judeok-up, Jaenae-ri 618 (36.989295°N; 127.782439°E). Because of the lack of rain, most rice paddies had been drained by agricultural water, while a lone fallow field was flooded by a ruptured farming water hose (Fig.). The site was similar to the only natural site reported for *Dryophytes suweonensis* in term of spatial setting, but different by its vegetation (Borzée & Jang, 2015). This attracted an abnormally high number of males and females from both *Dryophytes* species.

Spatial position of frogs and physical confrontation

For each calling frog within the submerged field, we recorded its position in relation to the edge of the submerged field with a range finder (SD 60; Sincon; Taichung, China), at 5 cm resolution. Data were collected for 10 male *D. japonicus*, two amplexed *D. japonicus* pairs, 16 male *D. suweonensis* and three amplexed *D. suweonensis* pairs. While measuring the distance to the edge of the submerged field for all calling individuals, we detected a male *D. japonicus* moving towards a calling *D. suweonensis*. We described sequence by sequence the resulting physical struggle between the two individuals.

Statistical analysis

To confirm the observation by Borzée et al. (2016b) on microhabitat segregation, we ran a Mann-Whitney U test on the distance to the edges of the submerged field between the two species. Then, to assess the continuity of the pattern, we ran a Mann-Whitney U test between the distances to edges of the submerged field for the amplexuses of the two species. Mann-Whitney U tests were selected due to the non-normal distribution of the data, but the similar shape of each dataset. All statistical analysis were run with SPSS v21.0 (SPSS, Inc., Chicago, USA), with *p*-values set at 0.05 for significance. The physical interaction between the males of the two species is described in the form of an ethogram.
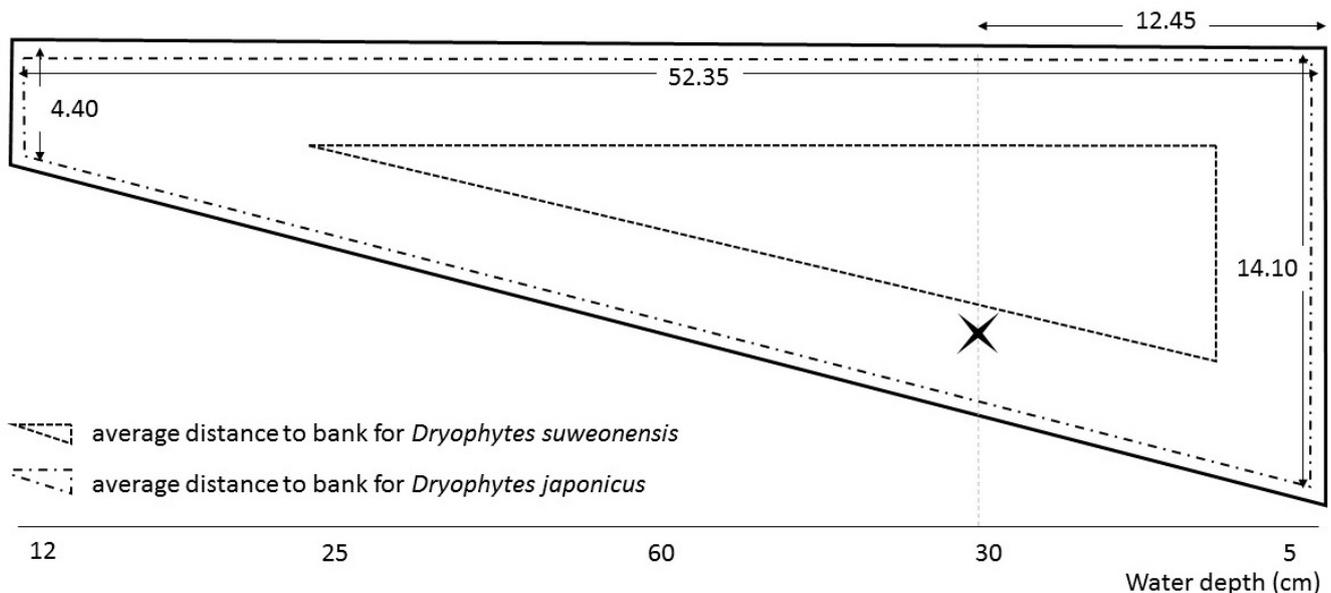

Fig. Line drawing of the site where the physical interaction between the two individuals took place. The inner-dotted-line is the average distance to the edge of the submerged field for *Dryophytes suweonensis* (4.48 m) and the outer-dotted-line is the average distance to the edge of the submerged field for *D. japonicus* (1.79 m). The star represents the place where the interaction between the two species took place.

Results

The submerged field was trapezoidal, with the two parallel edges 4.40 and 14.10 m long, and the longest edge 52.35 m long (Fig.). The water was between 5 and 60 cm deep, with a modal depth of 40 cm.

Spatial positioning

Male *Dryophytes japonicus* ($n = 10$) were on average 1.79 ± 0.83 m (mean $\pm$ SD) away from the closest edges of the submerged field (range = 0.53–3.53 m) and male *D. suweonensis* ($n = 16$) were on average 4.48 ± 1.09 m away from the closest edge (range = 2.98–6.10 m). This is a significant difference between the positions of the two species within the submerged field (Mann-Whitney U test; $U = 5.00$, $Z = -3.95$, $p < 0.001$).

The amplexed *D. japonicus* pairs ($n = 2$) were on average 3.77 ± 0.79 m away from the closest edge, while the amplexed *D. suweonensis* pairs ($n = 3$) were on average 4.78 ± 0.51 m away from the closest edge. The distance to the edge of the submerged field for the amplexus of the two species was not significantly different (Mann-Whitney U test; $U = 1.00$, $Z = -1.15$, $p = 0.248$).

Physical interaction

The physical interaction between the males of the two species took place 3.05 m away from the edge, 12.45 m away from the longest of the two parallel edges (Fig.). This was within the overlap between the two species described above (2.98 m to 3.53 m away from the closest edge of the submerged field).

The male *D. suweonensis* was calling on a twig, roughly parallel to the water, 6.2 cm above water level (Table). The male *D. japonicus* jumped from the edge of the submerged field, swam towards the twig, and set to climb on it. Once within reach, the male *D. japonicus* attacked the male *D. suweonensis*, which had stopped calling when the competing male reached the twig. The male *D. japonicus* aimed at biting while "pushing/taking support" on the body of its opponent with its forelimbs. The attack stopped two seconds later, with the male *D. japonicus* taking two steps backward, and the two opponents staying immobile for four more seconds. The male *D. japonicus* then walked towards the male *D. suweonensis*, which took three steps backwards and jumped into the water. The total length of the event lasted seven seconds, from the first physical contact to the spontaneous self-withdrawal of the male *D. suweonensis* jumping into the water (Table). The male *D. suweonensis* escaped towards the centre of the water body and the male *D. japonicus* started producing advertisement calls 18 seconds later.

Table. Descriptive ethogram for the physical confrontation between the male *Dryophytes japonicus* and the male *D. suweonensis*. The calling activity displayed by either male before and after the confrontation is representative of the purpose of the fight: the acquisition of a calling perch

Time (sec)	Male *Dryophytes suweonensis*	Male *Dryophytes japonicus*
–	Calling	Swimming
–	Non-calling	Climbing on twig
0	Immobile	Biting
2	Immobile	Withdrawing
6	Immobile	Immobile
7	Jumping away	Moving forwards
18	–	Calling

Discussion

Our observations report a second type of competition between *Dryophytes japonicus* and *D. suweonensis*: interference competition for calling sites, in non-natural conditions. At the difference with other studies (Kim, 2015; Borzée et al., 2016b), there was an overlap between the maximum distance to the edge of the submerged field for *D. japonicus* and the minimum distance to the edge for *D. suweonensis*. This overlap likely results from the hydric stress bringing all frogs together in an area where a ruptured water pipe flooded a fallow field. As the physical interaction took place within this area, we hypothesise that it was an artefact resulting from the human modifications to the landscape. This is also the highest number of *D. suweonensis* reported at a single calling site, and thus resulting in interference competition for a rarefied resource. We expect the size of the site not to be the key to the interpretation of these results, as segregation at smaller sites has been observed (Borzée et al., 2016b). However, the object of the competition, i.e. a calling perch, is readily understandable.

The male *D. suweonensis* escaping towards the centre of the water body, usually not populated by *D. japonicus*, follows the ecological knowledge on microhabitat use for these species. It is however interesting to note that although non-significant, the distance to the edge of the submerged field for the amplexuses of the two species follows the same segregation pattern. It is so far unclear if the low sample size is the reason for the non-significance in distance to the edge of the submerged field between the two species, or if females move around to lay eggs in a random fashion to increase offspring survivorship, such as in Bibron's toadlet (*Pseudophryne bibronii* Günther, 1859; Byrne & Keogh, 2009).

The outcome of the physical interaction may be the result of morphological differences between the two species as males *D. japonicus* are on average 5.22 % larger than males of *D. suweonensis* for snout-vent length (Borzée et al., 2013). Another explanation is that despite male-male physical confrontations being common in *D. japonicus*, this is the first such observation for *D. suweonensis* and the species may not express this behaviour. Besides, the lack of behavioural answer from *D. suweonensis* to the attack by *D. japonicus* could be interpreted as the result of signals non-perceivable by the observer, such as chemical communication observed in reed frog species (Hyperoliidae; Starnberger et al., 2013). Our observations also potentially explain the dynamics for the numerous *D. japonicus* and the endangered *D. suweonensis* in Korea: when calling sites are limited, interference competition could be a contributing factor to the decline of *D. suweonensis*.

Acknowledgements

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ИНТЕРФЕРЕНЦИОННАЯ КОНКУРЕНЦИЯ МЕЖДУ КВАКШАМИ (HYLIDAE) КОРЕИ, ОБУСЛОВЛЕННАЯ ВОДНЫМ СТРЕССОМ

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Конкуренция основана на типе и важности запрашиваемого ресурса, а взаимодействие усиливается с учетом важности данного ресурса. Одной из наивысших степеней интерференционной конкуренции является физическое взаимодействие за данный ресурс. Древесные лягушки *Dryophytes japonicus* (обычный вид) и *D. suweonensis* (исчезающий вид) конкурируют за пространственные ресурсы для осуществления призывных сигналов. Мы рассмотрели случай прямой интерференционной конкуренции из-за искусственного водного стресса, вызванного изменениями в системе орошения рисовых полей. В этих специфических условиях было представлено необычно большое количество самцов обоих видов, собранных на одном затопленном поле. Сначала мы обнаружили, что самцы распределены по следующей схеме: с *D. japonicus* по краям и *D. suweonensis* в центре обводненного поля. Однако не было значительных различий в расстоянии до края поля для представителей обоих видов. Из-за большого числа особей и небольшого размера участка области, используемые самцами обоих видов, частично перекрывались, что, таким образом, приводило к физическому взаимодействию между самцами двух видов. В результате *Dryophytes japonicus* смог занять место для призывных криков и вытеснить самца-соперника. Мы последовательно описали здесь взаимодействие, потенциально представляющее общий результат интерференционной конкуренции между этими двумя видами.

Ключевые слова: *Dryophytes japonicus*, *Dryophytes suweonensis*, интерференционная конкуренция, корейские квакши, физическая борьба