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Survival of Narrow-mouthed Toad, *Kaloula borealis* (Barbour, 1908), tadpoles before and after flooding of a river in South Korea

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The survival and reproduction of amphibians are closely associated with water quality, water availability, and rainfall patterns, all of which influence breeding conditions and population dynamics (Walls et al., 2013; Do et al., 2021). Because amphibian species differ in their preferred breeding habitats depending on water quantity and depth, alterations in precipitation regimes may affect their survival and reproductive success in different ways (Do et al., 2022a; Wren et al., 2024). An increase in precipitation may negatively affect the survival of amphibians by flooding rivers and streams, destroying existing tadpole habitats or dispersing tadpoles to other habitats, which may influence amphibian diversity and abundance (Joly and Morand, 1994; Brandão and Araújo, 2008; de Oliveira et al., 2009; Kupferberg et al., 2011). Therefore, hydrological changes can represent an important factor influencing aquatic amphibian populations (Walls et al., 2013; Adamski and Łaciak, 2024).

The Narrow-mouthed Toad, *Kaloula borealis* (Barbour, 1908), is widely distributed across northeast China and the Korean Peninsula (Borzée, 2024). Although the species is currently classified as Least Concern (LC) on the IUCN Red List, it has been designated as an Endangered Species Class II by the Korean Ministry of Environment due to habitat loss associated with development (Lee and Park, 2016; Amphibian Specialist Group, 2020; NIBR, 2020). This species is distributed throughout the territory of the Republic of Korea, including Jeju Island, and mainly inhabits low-altitude riverbank grasslands, ponds, and farmland (Do et al., 2017, 2022b; Kim et al., 2024a). They breed during the rainy season from June to August, making it the latest breeder among all amphibians living in the Republic of Korea, and they are rarely observed outside of the breeding season (Ko et al., 2012; Kim et al., 2021, 2024b; Groffen et al., 2022). One female spawns between 1800–2100 eggs, which hatch into tadpoles within 48 hours, and come up to the land after metamorphosing into juvenile forms within 20 days (Lee and Park, 2016; Rho, 2024). *Kaloula borealis* exhibits a marked preference for breeding in puddles of stagnant water that have been suddenly formed by rainfall over existing ponds (Jung et al., 2013; Do et al., 2025). *Kaloula borealis* prefers a water depth of 10–30 cm, which is relatively shallow compared to other amphibians (Jung et al., 2013; Cho and Shim, 2016). Therefore, the breeding characteristics of *K. borealis* (e.g., breeding during the monsoon season, explosive breeding over a short period) may make its populations vulnerable to sudden flooding events. In this study, we observed that fully submerged *K. borealis* tadpoles due to a river flood were not washed away to other areas for the first time and inferred the cause of this phenomenon based on narrow-mouthed toads' habitat and behavioural characteristics.

A field survey was conducted on 14 July and 16 July 2024, at the riverside located in Sejong-dong, Sejong Special Self-Governing City, Republic of Korea, to investigate the inhabitation and abundance of the tadpoles of *K. borealis* before and after flooding. The survey area is a grassland park under Geumnam Bridge, upstream of Sejong Barrage. Temporary puddles in the park are used as breeding sites by *K. borealis*, around which bicycle roads and sidewalks are present (Fig. 1A, 2).

The tadpoles observed at the study site were identified as *K. borealis* based on morphological characteristics.

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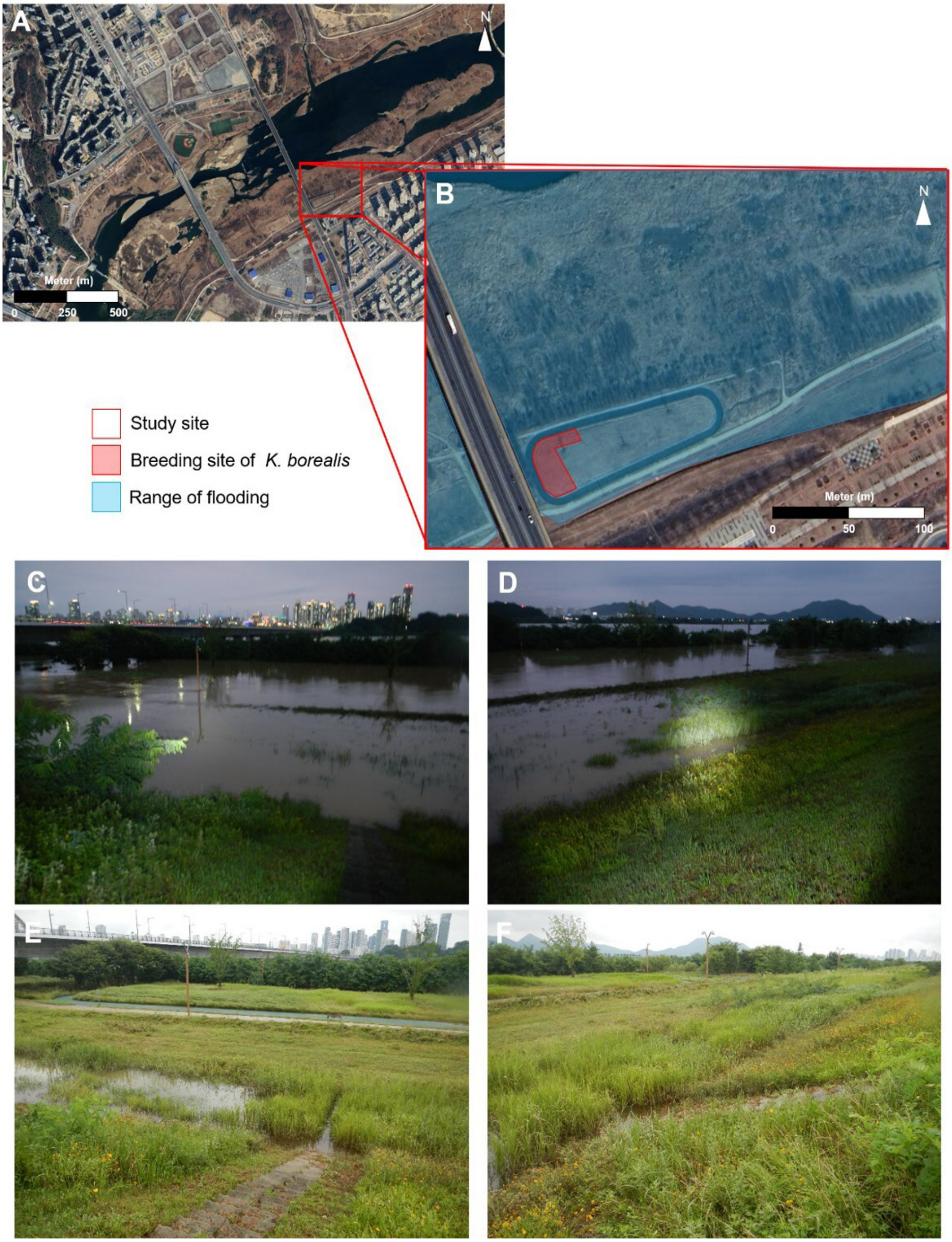

Figure 1. Breeding site of *Kaloula borealis* on the bank of the Geum River in Sejong, Republic of Korea. (A, B) Area where the flood happened. (C, D) Area flooded due to heavy rains on 15 July 2024. (E, F) Area after the water had completely drained away on 16 July 2024. Photos by Sang-Cheol Lee.

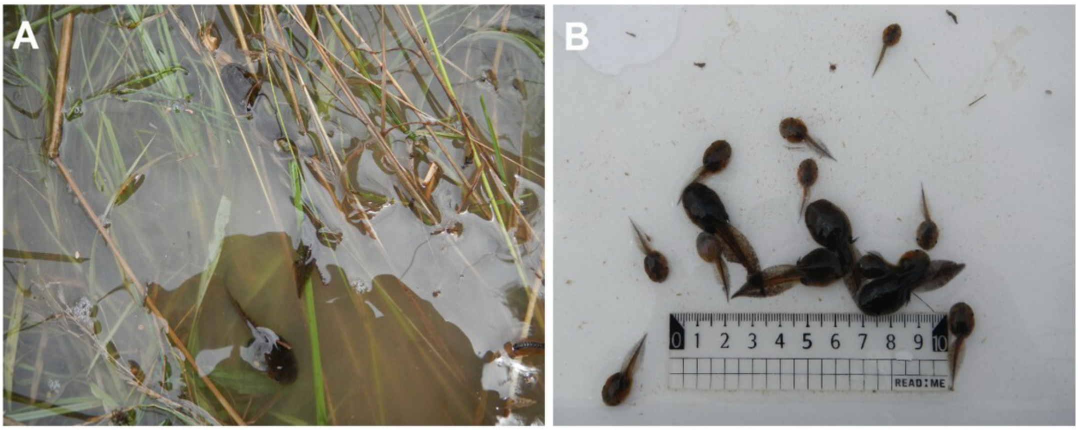

Figure 2. *Kaloula borealis* tadpoles observed after the flood at a breeding site near the Geum River, Sejong, Republic of Korea. (A) Tadpoles swimming in a puddle in the grassland within the breeding site. (B) Tadpoles observed on a white plastic board with a ruler placed beneath the water surface for species identification and size comparison. Photos by Sang-Cheol Lee.

Namely, tadpoles of *K. borealis* have a dorsoventrally flattened body, and the tail fin originates from the posterior end of the body. The dorsal surface is yellowish to brown, and some individuals possess a single yellowish-white stripe along the mid-dorsal line. The eyes are positioned laterally on both sides near the margins of the body (Lee and Park, 2016; Do et al., 2025).

We visually counted the number of *K. borealis* tadpoles swimming in the puddles for one hour (10:00–11:00 hrs) along the same route before (14 July 2024) and after (16 July 2024) the flooding using the visual encounter survey (VES) method to examine the survival and abundance of *K. borealis* tadpoles (Jung et al., 2002; Wren et al., 2024). The survey was conducted by three observers, who slowly walked within the breeding site while visually counting tadpoles. Each observer conducted the survey sequentially and approximately 20 minutes were spent per observer. Because visual surveys of tadpoles are likely to underestimate actual abundance the highest count recorded among the three observers was used as the final estimate of tadpole abundance (Jung et al., 2002).

We also collected hourly water level (m) information at upstream of Geumnam Bridge from the Geumgang River Flood Control Station (GRFCO, 2024) and obtained daily average temperature (°C) and precipitation (mm) data from the Korean Meteorological Administration (KMA, 2024) to check the water level and climate environment of the surveyed area. We collected ten days of environmental information between 10 and 19 July 2024.

It rained every day from 10 July until 18 July 2024. Due to heavy rainfall on 14 (182.70 mm) and 15 (283.70 mm) July, the water level of Sejong Barrage rose to 20.83 on 15 July and 17.38 m on 16 July (Fig. 3). We observed a maximum of 223 *K. borealis* tadpoles on 14 July, before flooding, with the three independent counts recording 192, 215, and 223 individuals. It was not possible to examine the survival of *K. borealis* tadpoles during the day and night on 15 July due to flooding (Fig. 1C, D). On 16 July, the breeding sites of *K. borealis* were visible again after flooding, and the three independent counts recorded 187, 190, and 211 individuals (Fig. 1 E, F; Fig. 2).

Although the breeding sites of *K. borealis* around Sejong Barrage were completely submerged due to a short-term heavy rainfall, the survival of the tadpoles at the same breeding sites was confirmed after the flooding. Moreover, the maximum count of tadpoles showed little change from 223 to 211 individuals, indicating that the population size was not affected.

We believe that *K. borealis* tadpoles were not flushed downstream because of the environmental characteristics of the breeding sites. Unlike other anuran species that inhabit the Republic of Korea, only *K. borealis* spawns during the rainy season (late summer) in temporary wetlands composed of reeds and grasslands, near rivers or streams, with a low altitude of 50 meters or less (Jung et al., 2013; Lee and Park, 2016). *Kaloula borealis* metamorphoses in one place from the tadpole stage to young adults (Jung et al., 2013;

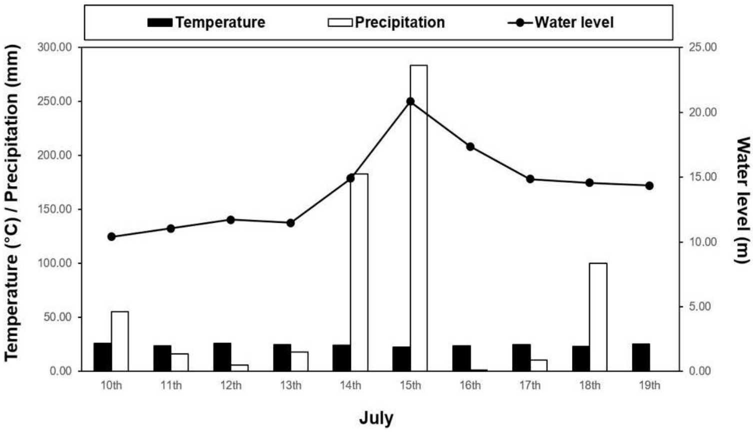

Figure 3. Changes in temperature, precipitation, and water level from 10 to 19 July 2024, including the heavy rainfall that occurred on 14 and 15 July 2024.

Do et al., 2025). In general, the probability of tadpoles being swept away by floods is directly proportional to the distance of the amphibian breeding site from the rivers and streams. For example, tadpoles of American Bullfrogs (*Lithobates catesbeianus*) and Blanchards' Cricketfrog (*Acris blanchardi*) inhabiting riverside wetlands are less susceptible to damage from floods than other species. Those species maintained their presence in the area because they utilise the edge of the river with relatively slow water flow when the water was flooded (Grant et al., 2015). Similarly, it is likely that most of the *K. borealis* tadpoles were not washed away because the flow velocity remained relatively low despite the flooding of the breeding site.

It is also plausible that the *K. borealis* tadpoles seek refuge under reeds or rocks in order to evade the rapid currents caused by the flood. Previous studies on the behavioural characteristics of anuran tadpoles showed that tadpoles of some anuran tadpoles hid under plants to avoid being flushed due to the increased flow velocity (Richter and Azous, 1995; Littlefair et al., 2021). For instance, Yellow-legged Frog tadpoles (*Rana boylii*) move freely at low flow velocity (0–2 $cm \cdot s^{-1}$) and hide between rocks when the flow velocity increased to avoid being flushed from their habitat (Kupferberg et al., 2011). Therefore, *K. borealis* tadpoles may hide in the surrounding terrain features (e.g., grass under the water surface and reeds) to evade the effects of floods. *Rana boylii* tadpoles became less capable to withstand the flow as they grew larger and reached later developmental stages (Kupferberg et al., 2011). However, since the sizes of tadpoles observed in this study varied highly, it is unlikely that there was a relationship between the flow velocity and tadpole sizes (Fig. 2). Consequently, unlike amphibians that breed during the dry spring season, tadpoles of *K. borealis*, which emerge during the summer monsoon season, may possess behavioural adaptations that allow them to tolerate sudden increases in water flow. Further studies examining flow velocity and *K. borealis* tadpoles are needed to clarify the relationship between tadpole size, developmental stage and resistance to water flow, as well as to identify behavioural strategies that may help them avoid rapid water flow.

This study has certain limitations in the method used to count tadpoles. Various methods are available for estimating tadpole population size, including visual surveys, capture–recapture, capture–removal, and dye-marking techniques (Jung et al., 2002; Wren et al., 2024). In this study, tadpoles were counted only through visual observation, which may underestimate actual abundance. Therefore, the highest count among the three observers was used as the representative value. In addition, factors such as water depth, turbidity, and vegetation may influence detection and reduce the reliability of visual counts. Despite these limitations, the difference in tadpole numbers before and after flooding was relatively small, suggesting that many individuals may have remained at the breeding site.

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