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The design method for concrete waterfront amphibian ladder along streams

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A B S T R A C T

How to balance environmental development and ecological conservation is one of the important issues of recent years. The main objective of this study is to investigate the behavioral patterns of amphibians on different substrates and slopes in order to provide necessary information to design a safe ecological amphibian ladder. Twenty *Buergeria japonica*, 20 *Buergeia robustus*, and 20 *Rana swinhoana*, were collected from the Wulai mountainous area in Taipei. The amphibians were divided into male and female samples, and their weight, body length, long jump, and high jump were tested. The effects of angle, material, temperature, and humidity on climbing ability were also discussed. The experimental results showed that the weight and body length of female frogs are larger than that of male frogs; the weight difference is 1.7-4 times; the body length is 0.9–2 cm higher. The orders of high jump and long jump of the three species are: *Buergeria japonica (♀) > Rana swinhoana(♀) > Buergeia robustus (♀) > Rana swinhoana (♂) > Buergeria japonica (♂) > Buergeia robustus (♂); Rana swinhoana (♀) > Rana swinhoana (♂) >Buergeria japonica (♂) > Buergeia robustus (♀) > Buergeria japonica (♀) > Buergeia robustus (♂)*. Comparison of climatic environments and climbing matrices showed that female frogs have better climbing ability than male frogs. The highest climbing value of *Buergeia robustus* in the low temperature and low humidity grass matrix 15°is 0.38 ($\times 10^{-2}$ N/g), that of *Rana swinhoana* in the low temperature and high humidity concrete matrix 15°is 0.25($\times 10^{-2}$ N/g). In general, the climbing abilities of frogs perform worst in low temperature and low humidity environments. There, it is suggested that the above environment can be the climate condition for amphibian ladder design. Moreover, the maximum climbing angle of frogs can be used as useful information when designing an amphibian ladder. This study also suggests that if there are more than two species of frogs in a habitat, the designer should use a lower slope angle to design so that the frogs with different climbing abilities can relocate or escape through an ecological amphibian ladder.

1. Introduction

Stream waterfront concreting is common in Taiwan. Due to the concrete structures on the banks of creeks for safety, the environment of the organisms living in the fragmented habitat becomes harsh (Hou et al., 2010). At present, the overdevelopment has led to damages of ecosystems, which not only damages the natural ecology, but also changes the species, abundance, and ecological structures of the ecosystem (Bin et al., 2014; Deyong et al., 2012). Chen (2003) and Wang (2006) indicated that habitat fragmentation is one of the primary causes of regional population extinction. Therefore, the amphibian corridor can be used for the habitation and transition of amphibians in the region (Chang et al., 2014).

Yu et al. (2012) reported that, in the urban area, the competition between environmental development and natural conservation is violent. The ecological corridor is a type of ecological engineering, which aims to alleviate the impacts of artificial production and recreation that leads to disappearance of the environments for existence, reproduction, and migration of organisms (Chen, 2011). Alan et al. (2012) suggested that the ecological corridor can enhance biodiversity. In the water, the fishway system assists fish in migrating, which reduces the barrier effect of large dams on the migration

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Fig. 1. Five kinds of substrates.

rate of fish under the interception of artificial facilities (Adam et al., 2012; Christos and John, 2012; Peter and Giuseppe, 2012). Fahrig et al. (1995) mentioned that the increased traffic volume in the world may indirectly result a decreased population size of amphibians, especially in densely populated regions. Lin (2006) indicated that the communication network fragments the living environment of local species, resulting in population extinction. Bohemen (1998) and Zhang et al. (2010) suggested that transportation, road construction, noise, and interference have negative effect on natural ecology. Thus, constructing ecological green corridors has become the main planning strategy (Wang, 2009).

Bergen et al. (2001) stated that ecological engineering is derived from human development and economy for protecting ecological environments; thus, the construction of infrastructures should minimize impacts on the ecological environment (Kuo, 2006). Elsevier (2012) indicated that the purpose of ecological fences is to avoid natural organisms entering project areas or roads, which can be fatal for them. Liu and Chen (2008) suggested that the highways of public works divide original habitats into two parts, and the habitat should be protected by ecological fences to prevent the organisms from entering artificial routes fatal to them.

There are two major species of amphibians in Taiwan, Anura and Caudata (Lue, 2006). The amphibians play an important role in ecosystem (Lue, 1996; Hou et al., 2008). For example, frogs are right in the middle of the food chain. They play an important role in consuming insects and are an important food source for birds, snakes, and other animals throughout the food web. Lue (1996) mentioned that different species of known amphibians in Taiwan have their favorite water areas during the tadpole period. Liou (2009) reported that *Buergeria japonica* the average body length of male frogs is 2.5 cm, and that of female frogs is 3.5 cm. According to Yang (2003), *Buergeria japonica* are often seen in the bottom of water ditches and on furrow banks and stones. They are very lively, good at jumping. Wu (2002) suggested that the *Buergeria japonica* tadpoles' temperature tolerance is higher than other species, and temperature tolerance is at least above 41 °C. Lin (2001) indicated that *Buergeria robusta* average body length of female *Buergeria robusta* is 1.48 times that of male frogs, the average body length of the male *Buergeria robusta* is 4.5 cm, and they often perform genital activity during clear unclouded nights. Lai (2001) reported that *Rana swinhoana* are distributed in the streams and ravines at altitudes of about 2000 m in Taiwan, the average body length of the male is 6.5 cm; that of female is 8.5 cm.

Although the importance of ecological corridor has been widely accepted by researchers and ecological engineers, yet, the necessary data to design a proper ecological corridor for amphibians are still insufficient. The main objective of this study is to investigate the behavioral patterns of amphibians on different substrates and slopes in order to provide necessary information to design an amphibian ladder for amphibian crossing dangerous sections, thus, helping to balance the ecosystem.

2. Materials and methods

2.1. Materials

2.1.1. Sample species selection

This study chose *Buergeria japonica, Buergeia robustus,* and *Rana swinhoana*, caught in Wulai mountainous area of Taipei (east longitude 121° 564379; north latitude 24° 869492).

2.1.2. Substrates selection

In this study, five common substrates of waterfront slope in Taiwan were collected from frog's natural habitat, including Grass (*Miscanthus floridulus*), Wood, Cobblestone, Concrete and Clay. The surface size for each test (i.e. substrate) was 40 cm × 30 cm (Fig. 1). The basic characteristics of the above substrates were introduced as follows. (1) Grass (*Miscanthus floridulus*) is a common plant in frog's natural habitat in Taiwan. The height of the grass is about 1.2–2 m. (2) Wood (Lauan wood) is obtained from the waterfront slope, and then cutting to be the test size. (3) Cobblestone is quite rough in its surface and it is a common substrate in frog habitat. The main components of Cobblestone are silicon dioxide, followed by a small amount of iron oxide and trace amounts of manganese, copper, alu-