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Construction and simulation of frog-ways in irrigation and drainage canal systems

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Background

Green and sustainable development of irrigated agriculture and protection of agricultural biodiversity are the inevitable requirements for the construction of modern irrigated districts in China. However, in order to ensure the efficient utilization of irrigation water, the construction of irrigation channels has been dominated by hard engineering, which has caused the loss and fragmentation of amphibian habitat, and the damage for ecological environment of the irrigation districts. The construction of amphibian corridors in irrigation channels is an important means to improve the connectivity of agricultural landscape and the migration efficiency of frogs in farmland.

Methods

This study selected a common Chinese frog, *Pelophylax nigromaculatus*, as the research subject because they are widely distributed in Jiangsu, and have important ecological, scientific and social values. We analyzed how the concrete-lined irrigation channels effected frogs' migration. We proposed the design of engineered modifications to allow frogs to escape from irrigation channels under different conditions. Meanwhile, to test and optimize the design method, we conducted physical model and numerical simulation experiment to make sure that it ran well.

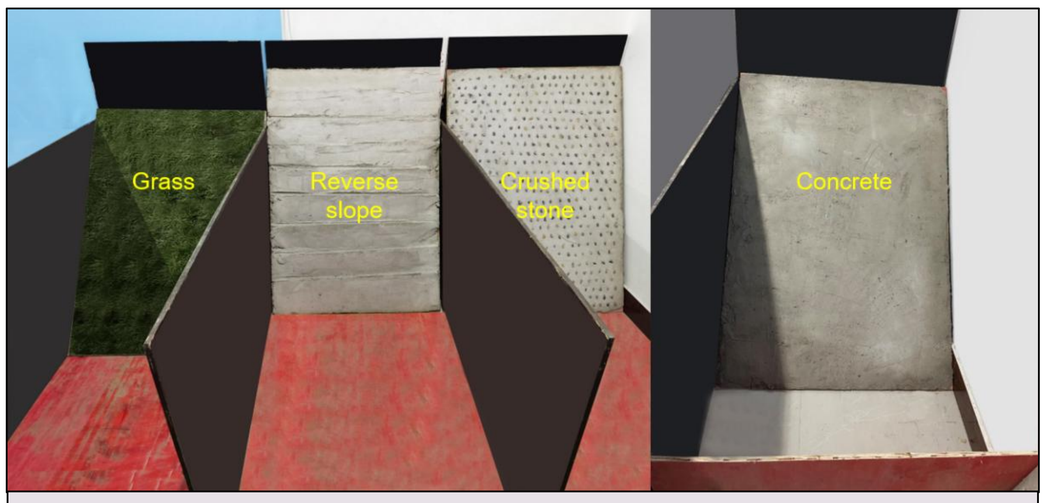

Fig. 2. The substrate materials were used to measure the limiting climb gradient of frog samples

Results and Conclusions

The details are as follows: 1) We obtained frogs' basic data such as the body size and behavioral characteristics through a series of behavioral testing, and analyzed the effects of concrete-lined irrigation channels on frog movement. The results showed that there was a significant positive correlation between the body size and the migration ability of frogs, reflecting in that the larger the body size was, the stronger the jumping ability was. There was a high correlation between body weight and the other three variables, and the linear regression model established with body weight as an independent variable had a good fitting effect, which could accurately reflect the correlation between the migration ability of frogs and their own biological factors.

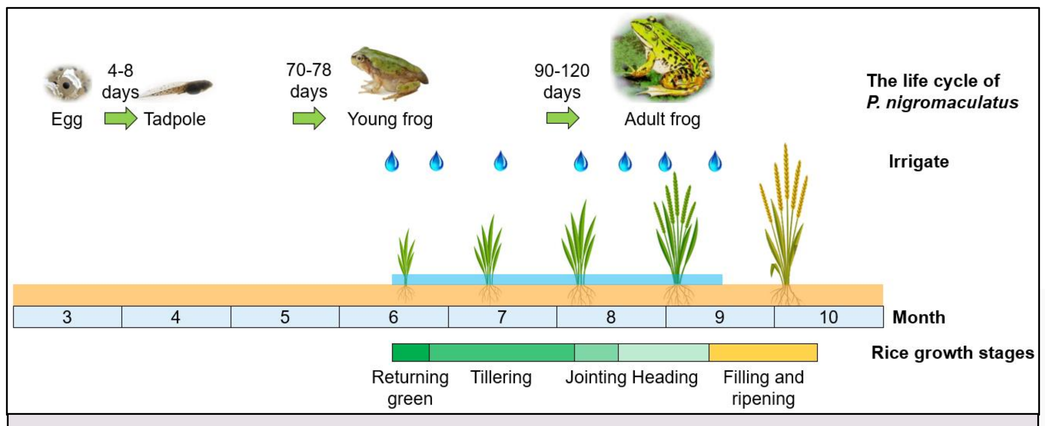

Fig. 1. *P. nigromaculatus* life cycle, rice growth cycle and irrigation cycle

2) According to grey correlation analysis, the most representative ones in migration ability were ♂14 and ♀18. Both of them could climb the concrete slope inclining no more than 40°. As a result, the design slope of concrete ditches should be less than 40°. Ecological design method of slope material was proposed according to the characteristics of frogs' upward jumping movement. The slope thresholds of reverse slope, grass and crushed stone were 50°, 60° and 65°, respectively. Compared with male frogs, female frogs had larger body size and stronger jumping and climbing ability, so the behavioral capability of male frogs should be considered more in the frog-ways design of irrigation channels.

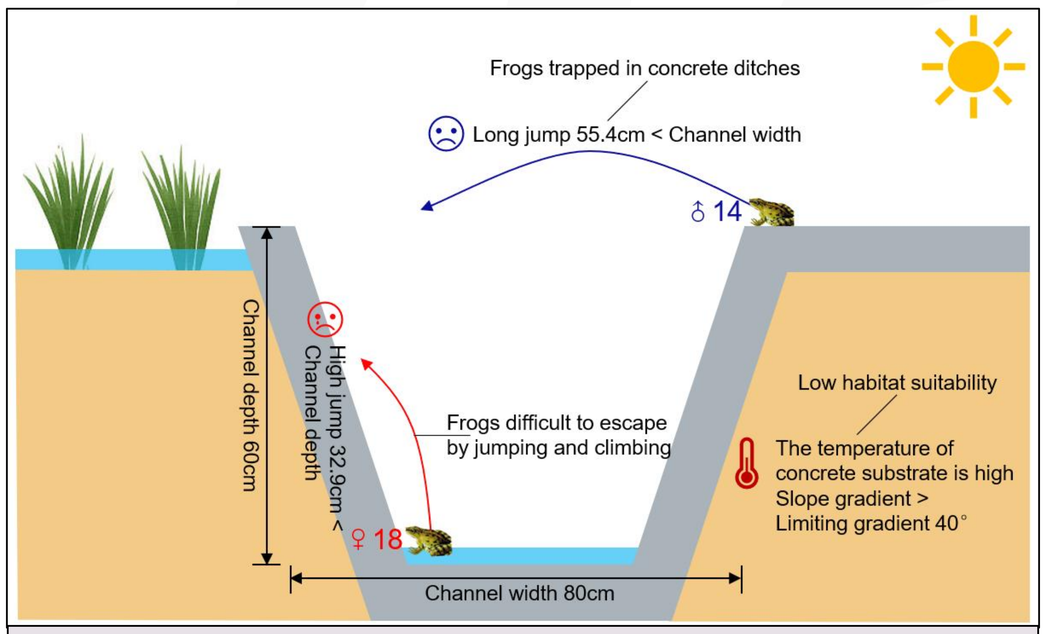

Fig. 3. Comparison of frogs' behavioral ability and structural parameters of concrete-lined irrigation channels

3) The results of the escape test showed that different types of frog-ways design methods suitable for non-irrigation period could help the vast majority of frogs escape from the concrete-lined irrigation channels, and the transverse design provides a slight benefit for frog escape. However, taking water conveyance efficiency, cultivated land utilization efficiency, and the costs and construction disturbance of engineered modifications into account, it is probably not justified. Both N5 and N11 could help the frogs escape successfully, while N5 covered only 36% of the area of N11. Therefore, we recommend a longitudinal design of simple concrete with slopes less than 55 degrees and crushed stone.