

Understanding anthropogenic impacts on anurans through life-history studies and a novel automated monitoring approach

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Background

Many species now live in human-modified climates and landscapes. Understanding how organisms respond to such environments is essential for explaining population persistence, and the extreme conditions created by human activities also offer opportunities to uncover the adaptive significance of the traits involved. Studying organismal responses to human activities is therefore valuable from both applied and fundamental perspectives.

Investigating anthropogenic impacts is particularly important for amphibians, the most threatened vertebrate class globally. In Japan, rice field intensification has been implicated in amphibian declines. One possible mechanism underlying amphibian declines is the shortened hydroperiod caused by modern drainage systems, which can dry up larval habitats. However, some amphibian larvae plastically accelerate development under desiccation risk, potentially enabling them to complete metamorphosis before rice paddy drainage. Therefore, in this thesis, I first test this adaptive plasticity hypothesis in *Glandirana rugosa* (Ranidae), which has a long larval period and can be susceptible to hydroperiod changes.

Beyond focused studies on specific species, rapid global change demands broad-scale monitoring tools for detecting human influences on amphibians. Recent advances in deep learning techniques and increasingly affordable acoustic sensors enable automated acoustic monitoring of frogs. Because applications of deep learning in anurans are still few, I explore the potential of the novel automation tools for monitoring frog populations and breeding phenology.

Materials and Methods

In Chapter 2, I examined whether *G. rugosa* larvae advance their development in rice fields. I surveyed larval growth in rice fields and natural habitats and conducted a series of rearing

experiments to identify factors determining larval period.

In Chapter 3, I evaluated a deep learning model (ResNet50) for detecting calls of five frog species in passive acoustic data. In addition, I conducted regression analyses to test whether model outputs (number of call detections) predicted field counts of calling males and amplexing pairs.

In Chapter 4, I applied the automated monitoring approach in the context of invasive alien species detection. Two alien frog species (*Polypedates leucomystax* and *Rhinella marina*) are occasionally introduced into Iriomote Island, a biodiversity hotspot in Japan. To facilitate early detection of these species, I developed a call detection model using the BirdNET bioacoustic software. Model performance was then evaluated with field recordings that contain artificial playbacks of alien frogs' calls.

In Chapter 5, I applied the deep-learning pipeline to a 15-year acoustic dataset from Iriomote Island to assess phenological shifts at low latitudes, where few long-term animal phenological data are currently available. I quantified the calling activity of seven frog species with BirdNET and assessed phenological shifts during the 15-year study period. Using sliding time window analysis, I also estimated climatic cues that may be driving such shifts.

Results and Discussion

Chapter 2 showed that most *G. rugosa* larvae in rice fields metamorphosed before harvesting-season drainage, whereas larvae in cooler habitats frequently overwintered. In the rearing experiments, they metamorphosed earlier at higher temperatures, while water level, source population, photoperiod, and sex had no clear effects on the larval period. Therefore, this temperature-dependent developmental plasticity likely facilitated population persistence of *G. rugosa* under intensified rice field management. However, their development rate is not fast enough to metamorphose before mid-summer drainage, possibly precluding their occurrence in many rice fields.

In Chapter 3, the deep learning model accurately identified calls of five anuran species (precision 0.91–1; recall 0.75–0.98). I also found positive relationships between call detections

and field counts of both males and amplexing pairs for most species, but the relationships with amplexing pairs were weaker. This study demonstrates the effectiveness of a deep-learning pipeline to quantify the breeding phenology of males, although female breeding activity should be interpreted with caution.

In Chapter 4, the trained model successfully detected nearly all playback survey dates and identified breeding seasons of the two alien species, providing information that helps determine efficient monitoring periods for early detection (spring–autumn for *P. leucomystax* and year-round for *R. marina*).

In Chapter 5, long-term acoustic monitoring revealed that a winter-breeding *Zhangixalus owstoni* significantly shifted breeding timing (3.8 days later/decade), with suggestive evidence that recent climate warming contributing to this delay. None of the study species advanced their breeding significantly. These results contrast with commonly reported advancement of spring phenology at higher latitudes, underscoring the need for long-term phenological monitoring in low-latitude regions.

Conclusion

To understand anthropogenic impacts on amphibians, this thesis examined amphibian responses to major global change drivers—agricultural intensification and climate warming—and explored emerging automation tools that can significantly improve monitoring of amphibian populations and breeding phenology. This thesis revealed human influences on amphibian life history in an understudied context (metamorphic timing) and in data-poor regions. This thesis also highlighted the potential of deep learning–based automated acoustic monitoring for detecting range expansions and phenological shifts.