

## 8 Research Gaps and Future Directions

### 8.1 Unresolved questions

Despite the recognition of habitat fragmentation as a significant driver of amphibian invasions, there remain substantial gaps in understanding the specific interactions between fragmentation and invasion dynamics. Current research often focuses on the immediate impacts of fragmentation, such as changes in species distribution and abundance, but lacks a comprehensive understanding of the long-term ecological consequences (Evans et al., 2017). Additionally, the role of habitat fragmentation in facilitating the spread of invasive species through altered ecological interactions, such as increased competition and predation, is not fully understood (Falaschi et al., 2020). There is a need for studies that explore how fragmentation influences the ecological niches of both native and invasive amphibian species, potentially altering competitive dynamics and facilitating invasions.

Most existing studies on habitat fragmentation and amphibian invasions are short-term, limiting our ability to predict long-term ecological outcomes. Long-term studies are crucial to understanding the cumulative effects of fragmentation on amphibian populations, including genetic diversity, disease susceptibility, and population connectivity (Belasen et al., 2019). Such studies would provide insights into the temporal dynamics of invasions and the potential for native species to adapt to fragmented landscapes over time.

### 8.2 Emerging research directions

The integration of advanced remote sensing technologies and ecological modeling presents a promising avenue for advancing our understanding of amphibian invasions in fragmented habitats. Remote sensing can provide detailed spatial data on habitat changes, allowing researchers to monitor fragmentation patterns and their impacts on amphibian distributions in real-time (Marvier et al., 2004; Barron et al., 2020). Coupling these data with ecological models can enhance predictions of invasion risks and inform management strategies aimed at mitigating the impacts of habitat fragmentation.

Genetic studies offer valuable insights into how invasive amphibians adapt to fragmented environments. Research has shown that habitat fragmentation can lead to genetic erosion, which may affect the adaptive potential of amphibian populations (Neely et al., 2004). Investigating the genetic mechanisms underlying adaptation to fragmented habitats can reveal how invasive species overcome environmental challenges and establish themselves in new areas. Such studies could also identify genetic markers associated with invasion success, providing targets for conservation efforts aimed at preserving native biodiversity.

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## Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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