Spotted Salamander (*Ambystoma maculatum*) Reintroduction in Restored Flatwoods Wetlands in Lake County, Illinois

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Abstract:
A diverse amphibian assemblage historically occurred in MacArthur Woods. Land use changes including hydrological alteration and introduction of an invasive shrub presented threats to persistence of several species. Spotted salamanders, wood frogs, and spring peepers were extirpated from the site by 1999. Habitat restoration was undertaken to remove these threats. Surveys were conducted to determine the post-habitat restoration amphibian assemblage. Recolonization by the species of interest was limited by similar historical threats to populations in neighboring preserves. Source populations for reintroduction of spotted salamanders were located in a nearby county. Based on sensitivity analysis, no more than 10 percent of the annual breeding effort was removed from source populations. Feasibility assessment for the reintroduction effort tested hatching success and larval survival using *in situ* pond enclosures over two seasons. In 2007 a reintroduction effort commenced, using enclosures to continue monitoring vital rates. These rates are being incorporated into a population viability analysis. Juvenile survival rates are being collected using enclosures to monitor a subset of spotted salamander metamorphs in upland habitat. Drift fences encircling breeding ponds allow long-term monitoring of juvenile and adult movements and survival rates. Reestablishment of a breeding population will require additional augmentation.

Field Enclosures

To assess feasibility of reintroduction into restored wetlands, in situ enclosures (Fig. 1) were used to compare hatching success and larval survival rates:

- Between source sites and restored sites
- Among ponds within sites
- Between resident blue spotted salamanders (*Ambystoma laterale*) and translocated spotted salamanders in restored sites.

- Each enclosure contained one spotted salamander egg mass (Fig. 2).
- A general linear model nested analysis of variance was used for the statistical analysis.
- Field enclosures were used for feasibility assessment from 2005-2007.
- Hatching data and larval survival data from 2005-2007 were used to obtain field-based estimates of vital rates for population viability analysis.
- In 2007, enclosures were used as a headstarting method for the initial release of spotted salamanders for a reintroduction effort.

Figure 1. In situ pond enclosures in a restored pond.

Figure 2. Spotted salamander egg mass used for reintroduction efforts.

Population Viability Analysis I

A loop diagram was constructed to create a stage-structured population growth model for spotted salamanders (Fig. 1). I used vital rates from the literature to estimate stage-specific survival and fecundity rates. Using these rates, a matrix was created and input into Unified Life Models (ULM) as a discrete, environmentally stochastic model.

I ran two scenarios for population viability analysis. One scenario simulated a reintroduced population, starting with aquatic and juvenile stages only, rather than breeding adults. The second scenario simulated a source population with stable age distribution. The simulation of a source population facilitated evaluation of the impacts of removing individuals from source populations.

Sensitivity and Elasticity Analysis

To prevent adverse impacts to the source populations, sensitivity and elasticity analyses were conducted to determine the most critical life stages to population growth, and the proportion of the annual breeding effort that could be removed for translocation without detrimental effects on the source populations. Initial abundances and vital rates were increased and decreased in increments of 10%.

Population Viability Analysis II

- Population growth projections were re-run in ULM using revised estimates of aquatic stage vital rates based on field enclosure estimates from 2005-2007.
- The field-based estimates demonstrated an overall increase from the published rates (Table 2).
- In these simulations I used the number of individuals successfully released in 2007 as the initial abundance for the first stage. No population supplementation was included in this revised projection. The revised PVA yielded new projections for population growth and probability of extinction.

Figure 4. Spotted salamander metamorph.

Figure 5. Terrestrial habitat enclosures for estimation of juvenile survival rates.

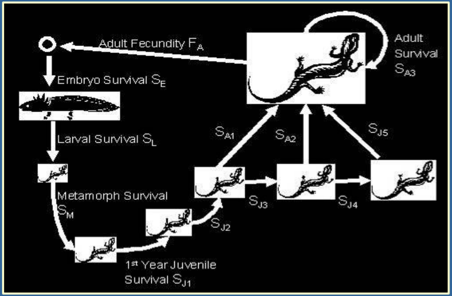

Figure 3. Loop diagram of life stages of spotted salamander.

Reintroduction Effort

In spring of 2007, field enclosures were used to monitor hatching success and larval survival of spotted salamanders in restored wetlands.

Successful metamorph spotted salamanders (Fig. 4) were batch marked with visible implantable elastomer (VIE), weighed, measured, and released at the pond edge for migration into the upland terrestrial habitat.

A subset of successful metamorphs were released into terrestrial habitat enclosures (Fig. 5) in an effort to obtain juvenile survival rates.

A subset of metamorphic blue-spotted salamanders were also released into terrestrial enclosures for comparison of a resident species that has persisted in the site with the reintroduced spotted salamander.

Table 2. Revised rates for population viability analysis II based on field estimates.

Parameter	Original Rate	Field Rate	% Increase
Embryo Hatching	0.22	0.25	13.7%
Larval survival	0.28	0.43	53.6%
Combined Aquatic Survival	0.06 = (0.22 x 0.28)	0.11= (0.25 x 0.43)	79.2%

Results-Field Enclosures

- There was no significant difference in hatching success or larval survival between source sites and restored sites.
- There were no significant differences in hatching rates and larval survival rates between spotted salamanders and blue-spotted salamanders in restored sites.
- There were significant differences in among pond hatching rates of spotted salamanders, related to dissolved oxygen levels.
- Ponds with hypoxic conditions and consistently low hatching success are undergoing further restoration management and were not selected as release sites in 2007.

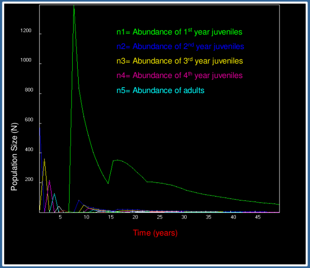

Figure 6. A 50 year projection of spotted salamander growth of a reintroduced population with original vital rates.

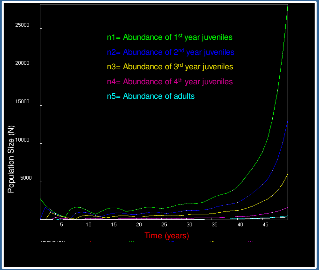

Figure 7. A 50 year projection of spotted salamander growth of a reintroduced population with revised vital rates.

Results: Reintroduction Effort

A total of 55 spotted salamander metamorphs were successfully released to the pond edge in 2007.

Four metamorphs were placed in terrestrial enclosures to estimate juvenile survival rates.

Follow-up efforts include four more reintroduction efforts to obtain the minimum viable population size of 100.

Post-reintroduction monitoring includes >6500 feet of drift fence surrounding breeding ponds to monitor movements of reintroduced spotted salamanders and egg mass surveys after 3-5 years to determine if breeding is occurring.

Results- PVA I and Sensitivity/ Elasticity Analyses

- The estimated minimum viable population size for reintroduction based on the initial simulations was 100 individuals ≈10,000 larvae for reintroduction.
- The intrinsic growth rate for a reintroduced population with only aquatic stages present at t_0 was r = 1.016 (± 0.007). Probability of extinction (PE) was 0.86 in 50 years, with PE of 1.00 in 66.2 years (Fig. 6).
- The intrinsic growth rate for a hypothetical source population with all stages present at t_0 was r = 1.088 (± 0.004). Probability of extinction did not differ from that of a reintroduced population.
- Both sensitivity and elasticity analyses demonstrated that adult life stages make the greatest contribution to the population growth rate.
- The sensitivity analysis indicated that 10% of the annual breeding effort could be removed from the source populations without detriment to their population growth rates.

Results: PVA II

- The simulations with only 55 individuals and the revised estimates of vital rates produced a greater population growth rate for reintroduced populations of r =0.99 without supplementation, and r = 1.13 with supplementation over five years (Fig. 7).
- In comparison with the simulation using the published rates, the time to extinction increased from PE = 1.00 in 27 years (Fig. 8) to PE = 1.00 in 60 years (Fig. 9) with the field-based rates without supplementation.

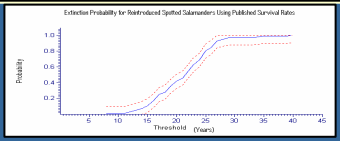

Figure 8. Extinction probability for reintroduced spotted salamanders using original vital rate estimates. N = 55 at t_0.

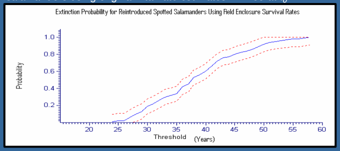

Figure 9. Extinction probability for reintroduced spotted salamanders using revised vital rate estimates. N = 55 at t_0.

Conclusions:

- In situ feasibility assessments provide valuable data for reintroduction efforts that can facilitate population modeling
- PVA is a useful tool in reintroduction efforts for:
  - Estimating target number of individuals necessary for successful reintroductions
  - Avoiding adverse impacts on growth rate of source populations
  - Identifying life stages most critical to population growth
- Field-based feasibility assessments for reintroduction can provide valuable site-specific estimates of vital rates.
- Headstarting spotted salamanders using in situ enclosures can improve the probability of persistence in a reintroduced population by increasing survival rates for aquatic life stages through reduced predation.

Acknowledgements: Dr. Richard B. King, Dr. Carl N. Von Ende, Lake County Forest Preserve District, Will County Forest Preserve District, Illinois Department of Natural Resources, Illinois Nature Preserve Commission, D.A.S. Charitable Fund, Northern Illinois University