2009. Proceedings of the Indiana Academy of Science 118(2):196–199

FROG POND, FISH POND: TEMPORAL CO-EXISTENCE OF CRAWFISH FROG TADPOLES AND FISHES

John G. Palis: Palis Environmental Consulting, P.O. Box 387, Jonesboro, Illinois 62952 USA

ABSTRACT. Biologists are alarmed by worldwide declines in amphibian populations and the extinction of amphibian species. The introduction of predators is among the causes of amphibian declines. Introducing predatory fishes into amphibian breeding habitat, in particular, can have detrimental effects on amphibian populations. Because their tadpoles are susceptible to predation by fishes, crawfish frogs (*Lithobates areolatus* [= *Rana areolata*]) typically breed in fishless wetlands. An exception, however, occurs in southern Illinois where crawfish frog tadpoles reach metamorphosis in fish-rearing ponds subsequent to the introduction of predatory fishes. Observational and experimental evidence suggest that crawfish frog tadpoles successfully co-exist with introduced predatory fishes by attaining a size refuge from predation. Results indicate that stocking ponds with predatory fishes does not necessarily reduce the potential of such ponds to serve as amphibian habitat. By coordinating the timing of fish introductions to reduce potential negative effects on amphibian larvae, fisheries biologists can improve habitat suitability for amphibians.

Keywords: *Lithobates areolatus*, *Rana areolata*, *Micropterus salmoides*, *Pimephales promelas*, amphibian, fish

Amphibian biologists are concerned about a worldwide decline in amphibian numbers and species (Blaustein & Wake 1990; Wyman 1990; Wake 1991; Stuart et al. 2004). Many amphibians are unable to coexist with predatory fish and are constrained to breeding in fishless water bodies (Gamradt & Kats 1996; Hecnar & M'Closkey 1997; Snodgrass et al. 2000). Introduction of predatory fishes into previously fishless water bodies has been implicated in the decline or extirpation of amphibians (Bradford 1989; Knapp & Matthews 2000).

Crawfish frogs (*Lithobates areolatus* [= *Rana areolata*]) breed in fishless temporary and semi-permanent ponds or small lakes (Phillips et al. 1999). Crawfish frogs are likely excluded from fish-occupied water bodies because their tadpoles are susceptible to predation by fishes (Werschkul & Christianson 1977). Crawfish frogs are believed to be declining over much of their range (Parris & Redmer 2005), and stocking breeding habitat with predatory fishes has been implicated as contributing to this decline (Phillips et al. 1999). However, the relative timing of frog breeding and fish stocking may serve to minimize the effects of fish predation on tadpoles. I conducted a study to evaluate this possibility in a pond used for breeding by crawfish frogs that is stocked annually with predatory fishes. The objectives were to examine the size relationships between crawfish frog tadpoles and fishes and experimentally evaluate the effects of fish predation on crawfish frog tadpoles.

Correspondence: John Palis; e-mail: jpalis@yahoo.com

METHODS

Field survey.—In March 2007 and 2008, I observed calling male crawfish frogs and crawfish frog egg masses in a pond on Crab Orchard National Wildlife Refuge (CONWR), Williamson County, Illinois. The approximately 1.2-ha pond is up to ca. 2.0 m deep and is largely devoid of vegetation. The nearshore bottom is partially covered with algae and pondweed (*Potamogeton diversifolius*), and a ≤ 2 m wide band of narrow-leaved cattail (*Typha angustifolia*) and bulrush (*Scirpus americanus*) occurs along ca. one-third of the shoreline. This pond is used to raise largemouth bass (*Micropterus salmoides*) for stocking into Crab Orchard Lake (Christopher Bickers, Illinois Department of Natural Resources pers. commun.). Juvenile largemouth bass and adult fathead minnows (*Pimephales promelas*) are introduced into the pond each spring. In 2007, largemouth bass were stocked on 16 May, and in 2008 they were stocked on 21 May. Fathead minnows are stocked as prey for the bass several times each spring and summer, beginning in April. Each fall, the pond is completely drained of water and all fish are removed. The pond drain is closed each winter and the pond subsequently re-fills with winter precipitation. Because water and fish are removed annually, the site mimics a fishless, temporary pond during the crawfish frog breeding season (typically late-February through early April in southern Illinois; JP pers. observ.).

Adult fathead minnows were stocked on 22 April 2008, and largemouth bass fry were stocked on 21 May 2008. When fishes were being released from the tank truck into the pond, I measured a sample of each fish species (n = 20) and crawfish frog tadpoles (n = 20). I captured tadpoles using a 1-mm mesh dipnet in April and a 4-mm mesh dipnet in May. I measured total length (TL; snout to tip of tail fin) and body width (BW; maximum width of body) of each tadpole to the nearest 0.5 mm with a ruler. I measured the total length (TL; snout to tip of tail fin) of the fishes to the nearest 0.5 mm with a ruler and gape width (GW; external mouth width from the outside of one maxillary bone to the other, with the mouth closed; Lawrence 1958) to the nearest 0.1 mm using calipers. Due to their diminutive size, I measured largemouth bass fry preserved in 10% formalin under 10.5-power magnification.

To gauge recruitment, I seined for late-stage, metamorphosing crawfish frog tadpoles (i.e., having 2–4 limbs) with a 6.1 m long, 1.2 m high seine having 3.2 mm mesh. On 11 June 2007 and 12 June 2008, I made ten 10-m long seine hauls through shallow (< 0.5 m), nearshore water. I counted and released all tadpoles and released all fishes. In 2008, I measured TL and GW of 20 largemouth bass and TL and BW of 20 crawfish frog tadpoles having no more than two limbs. After determining data were normally distributed, I used t-tests to compare mean TL and BW of tadpoles with the mean TL and GW of bass.

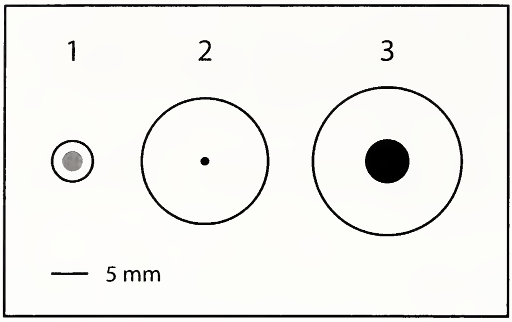
Predation experiment.—I examined survival of crawfish frog tadpoles caged with fish on the day fish were stocked. I examined survival of tadpoles caged with adult fathead minnows for 48 h from 22–24 April 2008. Containment of amphibian larvae with potential piscine predators for 24–48 h is sufficient to determine larval susceptibility to fish predation (Werschkul & Christianson 1977; Gregoire & Gunzburger 2008). Cages were 80 cm × 20 cm aluminum window screen cylinders. I placed 20 cages on the substrate, side to side in a single line, in water 30 cm deep. Each cage was held in place with a wire stake. I introduced 10 crawfish frog tadpoles into each cage and two adult fathead minnows into 10 randomly-selected cages. The remaining 10 fishless cages served as controls. Largemouth bass fry were one-fifth the size of the tadpoles (see Results) when introduced into the pond. Because largemouth bass fry were clearly incapable of preying upon or injuring the tadpoles, I did not test survival of tadpoles with bass in cages.

After the experiment, I counted tadpoles and examined them for injuries. I then released tadpoles and minnows into the pond. After testing data for violations of normality, I used t-tests to compare mean TL and BW of tadpoles with the mean TL and GW of minnows.

RESULTS

Field survey.—Adult fathead minnows introduced into the pond on 22 April 2008 were longer than crawfish frog tadpoles measured the same day; however, the body width of tadpoles was greater than the gape width of the minnows (see results of predation experiment). Largemouth bass fry introduced into the pond on 21 May 2008 were much smaller than crawfish frog tadpoles. Largemouth bass averaged (± 1 SD) 11.0 ± 0.7 mm TL and had a mean GW of 1.2 ± 0.1 mm, whereas the crawfish frog tadpoles captured the same day averaged 57.5 ± 4.4 mm TL and 17.0 ± 1.2 mm BW (Fig. 1).

Seining in June 2007 and 2008 revealed the presence of late-stage, metamorphosing crawfish frog tadpoles both years. I captured 168 crawfish frog tadpoles in 2007 and 44 in 2008. The discrepancy in catch among years is likely attributable to variation in sampling conditions. In 2007, seine hauls terminated at a mud bank. In 2008, when the water level was higher, inundated rigid, nearshore vegetation prevented the seine from reaching the bank. As a result, tadpoles were more likely to avoid capture in 2008. In 2008, crawfish frog tadpoles were longer than largemouth bass (tadpole mean TL = 70.1 ± 4.1 mm; bass mean TL = 64.2 ± 7.4 mm; t = 3.12, df = 38, P = 0.003) and wider than largemouth bass GW (tadpole mean BW = 20.0 ± 1.8 mm; bass mean GW = 6.0 ± 1.0 mm; t = 31.25, df = 38, P = 0.00001; Fig. 1).



Figures 1–3.—Measurements of fish gape width and tadpole body width over time. 1. Mean fathead minnow gape width (inner gray circle) and mean crawfish frog tadpole body width (outer circle) on 22 April 2008; 2. Mean largemouth bass gape width (inner black circle) and mean crawfish frog tadpole body width (outer circle) on 21 May 2008; 3. Mean largemouth bass gape width (inner black circle) and mean crawfish frog tadpole body width (outer circle) on 12 June 2008.

Predation experiment.—The mean TL and BW of 20 crawfish frog tadpoles introduced into cages on 22 April 2008 were 19.5 ± 3.3 mm and 5.5 ± 1.0 mm, respectively. The mean TL and GW of fathead minnows introduced into the cages were 53.0 ± 4.0 mm and 2.8 ± 0.2 mm, respectively. Fathead minnows were significantly longer than crawfish frog tadpoles (t = 28.72, df = 38, P = 0.00001), but tadpole BW was significantly wider than the GW of the minnows (t = 11.24, df = 38, P = 0.00001; Fig. 1). Survivorship of tadpoles after 48 h in cages with and without fathead minnows was 100%, and no tadpoles were injured by minnows.

DISCUSSION

Fathead minnows and largemouth bass potentially pose a threat to tadpoles small enough to be consumed. Fathead minnows are omnivorous, consuming benthic detritus, crustaceans, and other aquatic micro- and macroinvertebrates (Held & Peterka 1974; Litvak & Hansell 1990; Duffy 1998; Herwig & Zimmer 2007). Because fathead minnows consume crustaceans as large as amphipods and isopods, they are potential predators of small tadpoles. Juvenile largemouth bass less than 40 mm TL feed principally on aquatic invertebrates including small crustaceans, and insect nymphs and larvae (Applegate & Mullan 1967; Keast & Eadie 1985; Olson 1996). At 40–50 mm TL, juvenile largemouth bass shift to a fish-dominated diet (Applegate & Mullan 1967; Olson 1996). Largemouth bass ≥ 50 mm TL also consume tadpoles; and, in some systems, tadpoles comprise up to 41% of the diet of bass 261–336 mm TL (Hamilton & Powles 1983).

My observations suggest that the crawfish frog, a species that normally reproduces in fishless wetlands can, under the conditions observed in this study, successfully reproduce (i.e., produce late-stage, metamorphosing tadpoles) in water bodies containing predatory fishes. The likely mechanism permitting coexistence of crawfish frog tadpoles and predatory fishes is the order of colonization of each species into the pond. Because crawfish frogs breed approximately 1–2 months prior to the introduction of fishes, crawfish frog tadpoles have reached a size refuge from predation by the time each fish species is introduced. Attainment of a size refuge is a successful strategy for tadpole survival in the presence of piscine predators (Semlitsch & Gibbons 1988; Eklov & Werner 2000). Predaceous fishes are gape-limited, therefore prey body size relative to predator mouth gape determines which prey can be consumed (Hambright 1991). Tadpole BW was nearly twice as wide as adult fathead minnow GW and 14 times wider than largemouth bass fry GW when each species was introduced into the pond. Thus, crawfish frog tadpoles were too large to be consumed by either fish species.

This study demonstrates that stocking ponds with predatory fishes does not necessarily reduce the potential for such ponds to serve as amphibian habitat. By coordinating the timing of fish introduction to reduce potential negative effects on amphibian larvae, fisheries managers can increase habitat suitability for amphibians.

ACKNOWLEDGMENTS

I thank the following individuals for facilitating this study: Mike Brown and Tom Palmer (CONWR) for permission to conduct this study on the refuge (U.S. Fish and Wildlife Service Special-Use Permit numbers 33610-07052 and 33610-08034); Chris Bickers (IDNR) for providing management and stocking history, and for alerting me to stocking events in 2008; Alan Brandenburg (IDNR) for providing the bass fry; Pete Reiff (Logan Hollow Fish Farm) for providing the fathead minnows; Forrest Palis for help pulling the seine; Erin Palmer for recording data; Robert Hopkins for access to a dissecting microscope; Jeff Stewart for a key reference; and Adrienne Foster for rendering a much-improved version of the figure. I also thank Margaret Gunzburger, Ken Dodd, Daryl Karns, and an anonymous reviewer for constructive comments on this manuscript.

LITERATURE CITED

Applegate, R.L. & J.W. Mullan. 1967. Food of young largemouth bass, *Micropterus salmoides*, in a new and old reservoir. Transactions of the American Fisheries Society 96:74–77.

Blaustein, A.R. & D.B. Wake. 1990. Declining amphibian populations: A global phenomenon. Trends in Ecology and Evolution 5:203–204.

Bradford, D.F. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: Implication of the negative effects of fish introductions. Copeia 1989:775–778.

Duffy, W.G. 1998. Population dynamics, production, and prey consumption of fathead minnows (*Pimephales promelas*) in prairie wetlands: A bioenergetics approach. Canadian Journal of Fisheries & Aquatic Sciences 54:15–27.

Eklov, P. & E.E. Werner. 2000. Multiple predator effects on size-dependent behavior and mortality of two species of anuran larvae. Oikos 88:250–258.

Gamradt, S.C. & L.B. Kats. 1996. Effect of introduced crayfish and mosquitofish on California newts. Conservation Biology 10:1155–1162.

Gregoire, D.R. & M.S. Gunzburger. 2008. Effects of predatory fish on survival and behavior of larval gopher frogs (*Rana capito*) and southern leopard frogs (*Rana sphenocephala*). Journal of Herpetology 42:97–103.

Hambright, K.D. 1991. Experimental analysis of prey selection by largemouth bass: Role of predator mouth width and prey body depth. Transactions of the American Fisheries Society 120:500–508.

Hamilton, J.G. & P.M. Powles. 1983. Fish predation and other distinctive features in the diet of Nogies Creek, Ontario, largemouth bass, *Micropterus salmoides*. Canadian Field-Naturalist 97:47–56.

Hecnar, S.J. & R.T. M'Closkey. 1997. The effects of predatory fish on amphibian species richness and distribution. Biological Conservation 79:123–131.

Held, J.W. & J.J. Peterka. 1974. Age, growth, and food habits of the fathead minnow, *Pimephales promelas*, in North Dakota saline lakes. Transactions of the American Fisheries Society 103: 743–756.

Herwig, B.R. & K.D. Zimmer. 2007. Population ecology and prey consumption by fathead minnows in prairie wetlands: Importance of detritus and larval fish. Ecology of Freshwater Fish 16:282–294.

Keast, A. & J.M. Eadie. 1985. Growth depensation in year-0 largemouth bass: The influence of diet. Transactions of the American Fisheries Society 114:204–213.

Knapp, R.A. & K.R. Matthews. 2000. Non-native fish introductions and the decline of the mountain yellow-legged frog from within protected areas. Conservation Biology 14:428–438.

Lawrence, J.M. 1958. Estimated sizes of various forage fishes largemouth bass can swallow. Proceedings of the Annual Conference Southeastern Association Game & Fish Commissioners 11:220–225.

Litvak, M.K. & R.I.C. Hansell. 1990. Investigation of food habit and niche relationships in a cyprinid community. Canadian Journal of Zoology 68: 1873–1879.

Olson, M.H. 1996. Ontogenetic niche shifts in largemouth bass: Variability and consequences for first-year growth. Ecology 77:179–190.

Parris, M.J. & M. Redmer. 2005. *Rana areolata* Crawfish Frog. Pp. 526–528. *In* Amphibian Declines: The Conservation Status of United States Species (M.J. Lannoo, ed.). University of California Press, Berkeley.

Phillips, C.A., R.A. Brandon & E.O. Moll. 1999. Field Guide to Amphibians and Reptiles of Illinois. Illinois Natural History Survey, Manual 8, Champaign.

Porej, D. & T.E. Hetherington. 2005. Designing wetlands for amphibians: The importance of predatory fish and shallow littoral zones in structuring of amphibian communities. Wetlands Ecology & Management 13:445–455.

Semlitsch, R.D. & J.W. Gibbons. 1988. Fish predation in size-structured populations of treefrog tadpoles. Oecologia 75:321–326.

Snodgrass, J.W., A.L. Bryan, Jr. & J. Burger. 2000. Development of expectations of larval amphibian assemblage structure in southeastern depression wetlands. Ecological Applications 10:1219–1229.

Stuart, S.M., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman & R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783–1786.

Wake, D.B. 1991. Declining amphibian populations. Science 253:860.

Wyman, R.L. 1990. What's happening to amphibians? Conservation Biology 4:350–352.

Werschkul, D.F. & M.T. Christianson. 1977. Differential predation by *Lepomis macrochirus* on the eggs and tadpoles of *Rana*. Herpetologica 33: 237–241.

Manuscript received 15 June 2009, revised 4 October 2009.