Bullfrogs: Introduced Predators in Southwestern Wetlands

by
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In the American Southwest, much of the native fish fauna is facing extinction (Minckley and Deacon 1991); frogs in California (Fellers and Drost 1993) and frogs and garter snakes in Arizona (Schwalbe and Rosen 1988) are also in critical decline. Habitat destruction and introduced predators appear to be primary causes of native frog declines (Jennings and Hayes 1994), and habitat modification often yields ponds and lakes especially suitable for introduced species. Introduced bullfrogs (*Rana catesbeiana*) have been blamed for amphibian declines in much of western North America (e.g., Hayes and Jennings 1986; Leonard et al. 1993; Vial and Saylor 1993). Extensive cannibalism by bullfrogs renders them especially potent predators at the population level. The tadpoles require only perennial water and grazeable plant material; hence, transforming young can sustain a dense adult bullfrog population even if alternate prey are depleted. This may increase the probability that native species may be extirpated by bullfrog predation.

Introduced predatory fishes are apparently an important cause of frog declines (Hayes and Jennings 1986). They have been strongly implicated in one important case of decline of native ranid frog (family Ranidae, the "true" frogs; Bradford 1989). Some introduced crayfish may also be devastating in some areas (Jennings and Hayes 1994). In our study region, however, neither introduced fishes nor crayfish are dominant. We present results that sustain a "bullfrog hypothesis" for some native ranid declines, and we present our study as an example of how evidence accumulates to support such a hypothesis.

In 1985 we began documenting historical localities for wetland herpetofaunas (reptiles and amphibians), based on museum records and personal interviews, then revisited these and additional areas to determine current species' status. Results of this process, plus circumstantial evidence, suggested that the bullfrog was a primary cause for declines of leopard frogs and garter snakes in southern Arizona (Schwalbe and Rosen 1988).

Courtesy J.N. Carr, Arizona Game and Fish Dept.

Fig. 1. The worm has turned! In this unstaged photograph taken at Parker Canyon Lake, Cochise County, Arizona, 1964, an introduced bullfrog is swallowing a Mexican garter snake, normally a frog-eating species. Such predation appears to be destroying remaining populations of this garter snake in the United States.

In 1986-89 and 1992-93 we conducted removal censuses of bullfrogs at San Bernardino National Wildlife Refuge (SBNWR), Cochise County, Arizona. We simultaneously monitored native Chiricahua leopard frogs (*R. chiricahuensis*) and Mexican garter snakes (*Thamnophis eques*) at the sites of bullfrog removal. A control site, with no bullfrog removal, was established in comparable habitat at Buenos Aires National Wildlife Refuge (BANWR), Pima County, Arizona.

Evidence for Bullfrog Effects

Bullfrogs ate garter snakes, including Mexican garter snakes (Fig. 1), as well as numerous frogs, including young bullfrogs and the last observed leopard frogs on our intensive study areas. In addition, these frogs ate other frogs and snakes, lizards, fish, birds, and mammals in addition to many invertebrates (*see* also Bury and Whelan 1984).

We currently know of no examples of overlap between populations of the native leopard frogs *R. chiricahuensis* and *R. yavapaiensis* and bullfrogs in southern Arizona. Leopard frogs were abundant at both SBNWR and BANWR before bullfrog proliferation, and as recently as 1981, bullfrogs and leopard frogs were both still widespread at SBNWR (D. Lanning, The Arizona Nature Conservancy, unpublished data). Leopard frogs apparently were extirpated from our SBNWR study area by 1989.

In 1993-94 relict populations of Chiricahua leopard frogs (2-20 adults each) were found 5, 10, and 19 km (3.1, 6.2, and 11.8 mi) east of SBNWR. These populations are in areas not occupied by bullfrogs in habitats that may dry too frequently for non-native predators (personal observations), as seen in native frogs of the central valley of California (Hayes and Jennings 1988). These recent findings near SBNWR further support the bullfrog hypothesis in southeastern Arizona.

Checkered garter snakes (*Thamnophis marcianus*) are semi-terrestrial and coexist in abundance with bullfrogs. The highly aquatic Mexican garter snake, however, has only small, apparently declining populations where its habitat overlaps with that of bullfrogs. Because the bullfrog is also highly aquatic, its effects on the Mexican garter snake have been greater than on the checkered.

Although Mexican garter snakes do reproduce where they occur with bullfrogs, few young survive (Fig. 2). Once the young snakes outgrow vulnerability to bullfrog predation, they survive well; young adults marked in 1986-88 have been recovered at ages 7-10 in 1993, equaling and exceeding known ages for garter

snakes in the wild (Fitch 1965). All of the larger, older Mexican garter snakes have damaged tails from repeated bullfrog bites, and the largest and oldest one was found dying in 1993 with gross inflammation of the tail. It appears that without successful reproduction by some of these old snakes, the study population will shortly disappear.

Bullfrog Removal Experiments

Before 1993 intensive bullfrog removals were conducted two to three times per year at SBNWR. At one study pond, 854 large (80+ mm body length) bullfrogs had been removed from about 0.2 ha (0.5 acre) of habitat. After the 3 to 4 active-season months between removals, we saw a 50%-80% rebound toward preremoval numbers, and we observed weak evidence of positive effects on native leopard frogs and garter snakes (Schwalbe and Rosen 1988). Because a bullfrog can have as many as 20,000 eggs per clutch and has multiple clutches each year, the bullfrog was clearly uncontrollable at our initial level of effort.

Starting in 1993, we increased our efforts to remove bullfrogs from SBNWR by eliminating adult bullfrogs and catching juveniles as they matured.

Discussion

If adult-free bullfrog populations are attained at SBNWR during 1994, we predict that this will result in successful recruitment of juvenile Mexican garter snakes. We propose to translocate leopard frogs from nearby areas into fenced, newly created, bullfrog-free ponds. A primary objective is to have at least one natural area to save genetic stock of the local leopard frogs.

The SBNWR, with its numerous highly productive water sources, was probably a historical regional metapopulation (a set of populations connected by immigration and emigration) center (Gilpin and Hanski 1991) for leopard frogs. During times of drought, it was likely the mainstay of the species in the San Bernardino Valley system. Some of the unexplained frog declines in western North America (Cary 1993) may ultimately be traceable to catastrophic, localized extinctions in such refugia (Sjögren 1991; Bradford et al. 1993). An observation of probable rapid migratory spread by an introduced leopard frog species in Arizona (12 km/yr; Platz et al. 1990) suggests that individuals do disperse enough to consider metapopulation models. Information related to metapopulation phenomena could markedly enhance management for leopard frogs.

It is notable that the checkered garter snake, with an evolutionary background of geographical overlap with bullfrogs, succeeds with introduced bullfrogs in the West. Similarly, the accidentally introduced and rapidly spreading Rio Grande leopard frog (*Rana berlandieri*) in Arizona (Platz et al. 1990) also evolved with bullfrogs. In fact, this leopard frog is spreading into areas where the endemic Yavapai leopard frog (*R. yavapaiensis*) has been extirpated, probably by introduced predators as well as habitat alteration (Vitt and Ohmart 1978; Jennings and Hayes 1994).

Conclusion

Introduced predators such as the bullfrog can have devastating effects on faunas that evolved without equivalent predatory types. The bullfrog, as an exotic in the absence of key original enemies (the basses, pikes, snapping turtles, and water snakes of the eastern United States), attains tremendous population densities. Such non-native predators, in core population areas of native species, can lead to regional extinctions, and may account for some unexplained amphibian declines.

We now have abundant documentation that introduced predators, especially fish, crayfish, and bullfrogs, have caused major declines of frogs and other species in western North America. In Arizona, current trends suggest that inaction could lead to disappearance of three of five native leopard frog species within a decade. We urge, in addition to simply monitoring declines, active management where appropriate, within a controlled and documented framework. There is a pressing need for a practical, successful, and vigorously supported management strategy to preserve genetic stocks and restore habitats of native ranid frogs.

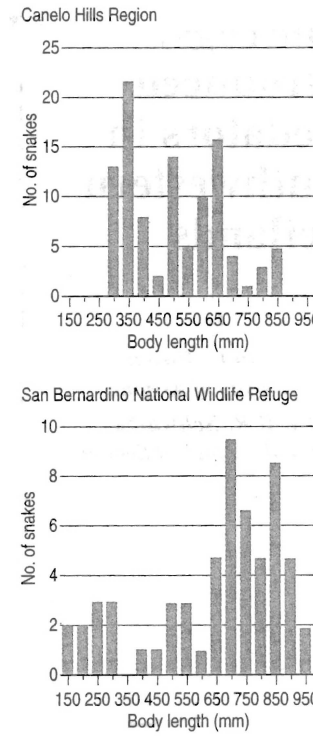

Fig. 2. Population structure of the Mexican garter snake. Numerous young snakes (200-700 mm, 1-3 years old) show successful reproduction in apparently intact populations (top), whereas bullfrog-affected populations (bottom) are composed mainly of older (700-1,000 mm, 3+ years old) snakes.

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