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Author(s): David L. Ward, Colton Finch and Heidi Blasius
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Could High Salinity Be Used to Control Bullfrogs in Small Ponds?

DAVID L. WARD, US Geological Survey, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, 2255 N. Gemini Dr, Flagstaff, AZ 86001;
COLTON FINCH, Utah State University, 5210 Old Main Hill, Logan, UT 84322; and
HEIDI BLASIUS, US Bureau of Land Management, 711 14th Ave, Safford, AZ 85546

Abstract

We examined survival of bullfrog (*Rana catesbeiana*) eggs and tadpoles at 3 ppt and 6 ppt salinity in the laboratory to determine if low-level salinity could be used to eradicate bullfrogs from small ponds that contain native fishes. Bullfrog eggs and tadpoles <10 days old experienced 100% mortality when held at 6 ppt salinity for 10 days. Bullfrog tadpoles 10-15 days old experienced significantly reduced survival when exposed to salinity of 6 ppt for 10 days. Older bullfrog tadpoles (>9 months old) appeared unaffected by 14 days of 6 ppt salinity. Salinity of 3 ppt did not impact survival of bullfrog tadpole eggs or tadpoles at any of the life stages we tested. Adding salt to ponds in the early spring to increase salinity to 6 ppt may be a cost effective way to eradicate bullfrogs from small ponds without harming native fishes.

Introduction

American bullfrogs (*Rana* [*Lithobates*] *catesbeiana*) prey on native fishes (Mueller et al. 2006), displace native frogs (Kiesecker et al. 2001) and utilize a large portion of the biomass in many small ponds making resources unavailable for native species (Kane et al. 1992). Attempts to remove non-native species from aquatic environments are common, but success is limited because few tools are available for managing invasive aquatic species (Dawson and Kolar 2003). Reports of bullfrogs being absent from locations with naturally high salinity (Reis 1999, Sadowski 2002) prompted us to examine elevated salinity as a tool for control of nuisance bullfrog populations in small pond environments.

Salt (NaCl) is one of the few chemicals approved for use on fish and safe for application within natural pond environments. Unlike many other chemicals, salt is not affected by high organic loads, so a single treatment can persist in a pond environment for many months until diluted. Most southwestern native fishes are known to be able to withstand salinities up to 6 ppt for several months (Stolberg 2012). In addition, high salinity is often used at fish hatcheries to reduce stress when transporting fish (Harmon 2009) and to remove ectoparasites such as Ich (*Ichthiopthirus multifiliis*; Ward 2012).

We conducted four separate laboratory experiments for 10-14 day durations at three salinity levels. These experiments were designed to evaluate if elevated salinity could interrupt development of bullfrog eggs and tadpoles and thereby be used to remove nuisance bullfrogs.

Methods

Bullfrog tadpole eggs were collected from naturally occurring egg masses in ponds at Bubbling Ponds Fish Hatchery, Arizona. Sixty eggs were placed into each of 12 different, 37.8-liter (L) aquaria filled with well water and maintained at 20°C ±2°. Tanks were randomly assigned to one of three salinity treatments (control, salinity <0.2 ppt, 3 ppt, or 6 ppt). The numbers of surviving tadpoles in each tank were counted after 10 days. This experiment was repeated a total of four times using tadpoles of increasing age collected from the same ponds during the months of June and July 2008. In Experiment Two, 20 bullfrog tadpoles <10 days posthatch (Gosner stage 20-25; Gosner 1960) were placed into 12, 38-L aquaria randomly assigned to salinity treatments and again monitored for 10 days after which survival in each tank was quantified. In Experiment Three, 13 bullfrog tadpoles 15-20 days post-hatch (Gosner stage 25) were placed into 12, 38-L aquaria randomly assigned to salinity treatments and again monitored for 10 days after which survival in each tank was quantified. In Experiment Four, 120 bullfrog tadpoles (>9 months old) (Gosner stage 26-35) were placed into one of three, 568-L fiberglass tanks with varying salinity (0, 3 ppt, and 6 ppt) and filtration and monitored for 14 days. In each experiment, tadpoles were fed spirulina tablets twice during the treatment period. An Oakton Instruments® low-range digital salinity meter and un-iodized granular table salt were used achieve the desired salinities in each treatment tank. Two-sample t-tests were used to compare the number of surviving tadpoles in each treatment group.

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RESULTS

Bullfrog eggs maintained at 6 ppt for 10 days did not hatch. Survival of bullfrog eggs at 0 ppt and 3 ppt salinity was approximately equal at 3-16% (Table 1). In Experiment Two, using 10-day old bullfrog tadpoles, no tadpoles survived after 10 days of 6 ppt salinity (Table 2). Bullfrog tadpoles maintained at 0 and 3 ppt salinity exhibited high survival (85-100%), although tadpoles held at 3 ppt salinity appeared smaller and less robust than controls. In Experiment Three, conducted with 15-20 day-old bullfrog tadpoles, survival was again equally high (76-100%) in the low salinity and control tanks. Survival at 6 ppt salinity, however, was significantly reduced (15 - 53%; $P<0.0009$, two-sample t-test; Table 3). In Experiment Four, adult bullfrog tadpoles (>9 months old), experienced no mortality at any of the salinities tested and appeared unaffected by 3 ppt or 6 ppt salinity.

***Table 1**. Total number of tadpoles surviving after 10 days at 0, 3 and 6 ppt salinity. Each tank started with 60 bullfrog tadpole eggs.*

Control	3 ppt	6 ppt
4	2	0
8	7	0
4	5	0
5	10	0

Table 2. Total number of tadpoles surviving after 10 days at 0, 3 and 6 ppt salinity. Each tank started with 20 tadpoles that were all less than 10 days old.

Control	3 ppt	6 ppt
20	20	0
20	17	0
20	18	20
20	20	0

***Table 3.** Total number of tadpoles surviving after 10 days at 0, 3 and 6 ppt salinity. Each tank started with 13 tadpoles that were all 15-20 days old.*

Control	3 ppt	6 ppt
13	12	2
13	12	7
13	10	3
13	13	2

DISCUSSION

Our results suggest that bullfrog tadpoles have increasing resistance to salinity with age and indicate that treatment regimes to control bullfrogs using salinity must occur when eggs are either unhatched or tadpoles are very young (<10 days old). Adding salt to ponds to artificially increase the salinity to 6 ppt in the spring may be effective at killing bullfrog eggs and young tadpoles. This method combined with mechanical removal of adults may increase the chances that bullfrogs can be eradicated from small ponds within 2 to 3 years. Application is likely limited to shallow ponds less than 1 surface acre as increasing the salinity in ponds larger than this would require quantities of salt that would be prohibitive to transport and apply. Although there are differences in salinity tolerance among frog species (Brown and Walls 2013), elevated salinities are also likely to negatively affect native amphibian populations (Karraker et al. 2008). Thus, this approach is probably only practical in cases where native amphibians have already been eliminated and bullfrogs need to be removed so that native species can be reintroduced.

Aquatic resource managers have very few tools available for managing invasive aquatic species (Dawson and Kolar 2003). Finding new techniques and tools for selective removal of introduced species is critical to the success of future conservation efforts. Artificially increasing the salinity of small ponds in the early spring may provide an additional tool for control of bullfrogs in areas where they have become problematic.

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