RESPONSE OF CALIFORNIA RED-LEGGED FROGS TO REMOVAL OF NON-NATIVE FISH

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ABSTRACT: As part of the mitigation for construction of the Los Vaqueros Reservoir in the upper Kellogg Creek Watershed, the Contra Costa Water District removed non-native fishes from managed stock ponds on the watershed. We found six species of fish in 7 of 90 ponds. Several ponds with fish were drained during the fall low-water period each year from 1998 to 2001. Water was pumped out of ponds and fish were removed with seines, throw nets, and dip nets. Ponds later recharged from groundwater springs. California red-legged frog (*Rana aurora draytonii*) adults were observed in ponds within weeks of recharge. Reproductive success for California red-legged frogs increased dramatically after predatory fish removal. Two ponds never had more than 2 juvenile California red-legged frogs prior to fish removal, but had > 450 juveniles after fish removal.

Key words: amphibians, California red-legged frog, juvenile, non-native fishes, stock ponds, success.

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Recent investigations into the current distribution of amphibians have reported marked declines in the geographic range of many species (Jennings and Hayes 1994, Stebbins and Cohen 1995, Adams 1999). While there are several theories suggested for the reasons behind these declines, many authors have attributed regional amphibian declines to the presence of exotic predators (Fisher and Shaffer 1996, Knapp and Matthews 2000, Matthews and Knapp 2000). The introduction of non-native fishes, in particular, has occurred in California for nearly 130 years (Curtis 1942, Moyle 1976). There is evidence that the extent of the impact of these introductions is negative on native ranid (Bradford 1989, Hews 1995, Hecnar and M'Closkey 1997, Knapp and Matthews 2000).

The California red-legged frog (*Rana aurora draytonii*) has declined in distribution and numbers for several decades (Hayes and Jennings 1986, Jennings and Hayes 1994, U.S. Fish and Wildlife Service 2003). This species is currently listed as threatened by the U.S. Fish and Wildlife Service (USFWS) (2003). Investigations into the reasons for its decline and suggestions for its recovery are being examined.

The proposal for construction of the Los Vaqueros Reservoir in eastern Contra Costa County, by the Contra Costa Water District (District), precipitated numerous mitigation requirements for disturbance to California red-legged frog populations, and loss of its habitat. Mitigation measures included the enhancement, protection, or creation of many existing aquatic habitat types. The USFWS recommended that all non-native fishes be removed from aquatic habitats in the Los Vaqueros Watershed as one of the many measures developed to enhance current habitat for red-legged frogs. We present the effects of removal of those fishes on different life stages of red-legged frogs.

METHODS

Study Area

The Los Vaqueros Watershed and Reservoir is in the upper Kellogg Creek Watershed, about 57 km east of San Francisco, California. Habitat in the 7,500-ha watershed consisted of chaparral, open water, rock outcrops, annual and perennial grassland, oak (*Quercus* spp.) woodlands, riparian wetlands, perennial drainages, ephemeral and seasonal wetlands, 68 stock ponds, and 22 constructed semi-permanent marshes. The dominant vegetation type was non-native annual grassland grazed by sheep and cattle. Many special-status wildlife species occurred on the watershed, including California tiger salamander (*Ambystoma californiense*), California red-legged frog, western pond turtle (*Clemmys marmorata*), and Alameda whipsnake (*Masticophis lateralis euyxanthus*).

Surveys

We conducted surveys at 90 ponds (68 stock ponds and 22 mitigation ponds) 6 times per year, 1998-2001 (Feb/Mar, Apr, Jul, Aug, Sep, Oct). Red-legged frog eggs, lar-

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vae, juveniles, and adults were counted during each pond survey. Juvenile red-legged frogs were those that were thought to have metamorphosed during the year of the survey (SVL < 4 cm); all others were considered adults. We also recorded other amphibians, red-legged frog predators, and vegetation characteristics at each site. Fishes encountered during surveys were identified to species and included brown bullhead (*Ameiurus nebulosus*), white catfish (*Ameiurus catus*), channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and mosquitofish (*Gambusia affinis*). Besides conducting surveys, we also questioned previous landowners of watershed lands about the distribution of fish species known to occupy ponds.

Ponds that were occupied by non-native fishes (N=7) were drained to remove fish. One or more of these 7 ponds were drained each fall from 1998 to 2001. Game fish were moved to the Los Vaqueros Reservoir for use in the recreational fisheries program. We used several pumps of various sizes (5 - 15.5 cm) to drain water from ponds. After several days, water levels were reduced to a depth of ca. 50 cm. We used seines, throw-nets, and dip nets to remove as many fish as possible. Water levels were further reduced to < 3 cm, and seines were again used to remove remaining fish. Long-handled dip nets facilitated removal of individual fish that escaped the seining attempts. We monitored ponds for several days to ensure that all fish were removed. Any remaining fish were removed by draining the small amount of water in the pond. Post-treatment monitoring determined that all 6 species of fish were successfully eliminated from the treated ponds.

In ponds with mosquitofish, we employed 2 additional methods. First, the bottom layers of mud were smoothed to reduce small pockets of water used as refugia by tiny fish immediately after draw down. One or more biologists crawled on hands and knees over the mud bottom while pushing a 46- x 243-cm (18- x 96-in) piece of plywood in front of him/her. The board was held at a shallow angle such that the edge nearest the biologist was slightly lower than the leading edge. Each person moved in concentric circles toward the deepest portion of the pond. This method squeezed the moisture from the mud and smoothed the surface. Then the excess water was pumped from the pond, leaving a smooth pond bottom with little standing water. Second, small amounts of household bleach (sodium hypochlorite) were applied to areas of ground water seepage and any remaining pockets and depressions that might have offered habitat for mosquitofish. We monitored ponds for several days to ensure that all fish were removed and retreated if necessary. After fish removal efforts were completed, ponds were allowed to recharge from ground water springs. Ponds filled to capacity, through ground water recharge and winter rains, within 3 months of treatment. Amphibian surveys were conducted subsequent to pond draining and recharge. All amphibian species encountered were identified to life stage.

RESULTS

California red-legged frogs were found in all ponds (range = 1 - 850) during each survey effort. We found 6 species of non-native fish in 7 ponds on the watershed (Table 1). Largemouth bass and catfish were removed successfully on the first draining treatment. Mosquitofish survived treatment in 2 ponds during the first attempt to remove them. A second attempt to remove mosquitofish occurred 2 years later with the addition of secondary efforts (i.e., mud smoothing and bleach application). Secondary efforts increased effectiveness of the removal of mosquitofish.

When non-native fishes were present, the highest number of red-legged frogs observed was 40 adults and

Table 1. Number of non-native fish removed from ponds at the Los Vaqueros Watershed, eastern Contra Costa County, California.

	Pond number						
Species observed	G2	G3	G5[a]	G7[a]	I2	I4	J3
White catfish	25	25	9	0	56	0	0
Brown bullhead	280	5,525	121	19	0	0	0
Channel catfish	75	0	24	0	0	0	0
Mosquitofish[b]	0	0	10,000	5,000	0	8,000	10,000
Bluegill	0	0	0	0	1	0	0
Largemouth bass	0	0	254	174	245	0	0

[a] also drained in 2001 to remove mosquitofish.
[b] numbers of mosquitofish are estimates

15 juveniles (Table 2). After fish removal, the highest number of red-legged frogs observed was 41 adults and 650 juveniles. Red-legged frogs were never observed in one pond (I2) prior to fish removal. However, we observed ca. 100 tadpoles and > 440 juveniles during a single survey after fish removal. Only 1 juvenile was recorded at pond G5 during 10 years prior to fish removal (Contra Costa Water District, unpublished data). Observations increased to 221 and 650 juveniles in the 2 years post treatment.

Table 2. Highest number of adult and juvenile California red-legged frogs observed in ponds before and after non-native fish removal at the Los Vaqueros Watershed, eastern Contra Costa County, California. Results expressed as adults/juveniles.

Pond	Number of Red-legged Frogs			
	1998	1999	2000	2001
G2	4/0A	17/9	32/166	30/1
G3	40/10	38/6[a]	27/6	30/41
G5[a]	2/1	3/0	9/221	41/650
G7[b]	11/5	17/0[a]	35/27	30/2
I2	0/0	0/0	0/0[a]	18/444
I4	0/3	4/15	3/30[a]	7/47
J3	1/7	1/0	3/0[a]	1/133

[a] year pond was drained

[b] also drained in 2001 to remove mosquitofish.

DISCUSSION

Our observations suggest fish removal is a practical management tool that can result in increased California red-legged frog use of managed ponds. We also found that the effort and time involved in removing fishes was inversely proportional to the size of the fish. Adult red-legged frogs occupied nearly all ponds in the watershed; including those that also contained non-native fishes. Numbers of adult frogs observed appeared to be positively correlated with higher densities of emergent vegetation (Hecnar and M'Closky 1996; Alvarez, personal observation). Also, Kiesecker and Blaustein (1998) reported a shift in microhabitat use of northern red-legged frogs (*R. a. aurora*) when sympatric with bullfrogs (*R. catesbeiana*) and smallmouth bass (*Micropterus dolomieui*). In one of our sites (I2), we recorded little emergent vegetation and no red-legged frogs prior to fish removal.

Although adult red-legged frogs were found with non-native fish at 6 of 7 ponds, there were few observations of juveniles and no observations of larvae or eggs at any of those ponds. We believe that this is indicative of a lack of reproduction or nearly complete predation of the larvae and juvenile cohorts. Red-legged frog larvae may take 4 to 13 months to metamorphose (Storer 1925, Fellers et al. 2001). We observed many overwintering larvae in the Los Vaqueros Watershed (12% of all ponds). This long larval stage may contribute to the vulnerability of this life stage to largemouth bass and catfish predation (Hews 1995).

Our post-treatment observations suggest a marked increase in larval/ juvenile survivorship after non-native fish removal. This may ultimately translate into an increase in breeding adults at each treated pond. Further monitoring of these ponds will include efforts to determine trends in adult population fluctuations.

Gill-nets have been used successfully to remove salmonid fishes from high elevation lakes without mortality to mountain yellow-legged frogs (*Rana muscosa*) (J. Kleinfelter, California Depart. Fish & Game, pers. comm.). Mountain yellow-legged frogs were observed soon after predatory fish were removed from lakes used by this ranid species. Similar results have been found with the same species by others (Knapp and Matthews 1998). It appears clear that when non-native predatory fishes are removed from mountain yellow-legged frog habitat, this species recovers quickly. Our evidence suggests that removal of non-native fishes increases the number of juvenile red-legged frogs. We suggest that one of the management tools used in the recovery of the red-legged frog should be the removal of non-native fish from aquatic habitat in this species range.

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