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POPULATION DECLINES OF THE NATIVE FROG, *RANA MUSCOSA*, IN SEQUOIA AND KINGS CANYON NATIONAL PARKS, CALIFORNIA

Sierra Nevada water bodies

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ABSTRACT—*Rana muscosa* (mountain yellow-legged frog) is one of a number of amphibians around the world that reportedly have declined in numbers in recent years in seemingly well-protected environments. In Sequoia and Kings Canyon National Parks, California, two study areas comprising the headwaters of seven creek systems were surveyed for *R. muscosa* and *Pseudacris regilla* (Pacific chorus frog) in 1978–1979 and again in 1989. *R. muscosa* was found at 27 sites greater than 200 m apart in 1978–1979, but at only one site in 1989, and the population at this site disappeared by 1991. In contrast, *P. regilla* was found at 15 to 17 sites both times. A comparison of 21 historical (1955–1979) and recent (1989–1990) records scattered throughout the parks showed that *R. muscosa* remained at only 11 of these sites in 1989–1990. A similar comparison of 24 historical and recent records elsewhere in the Sierra Nevada showed that *R. muscosa* remained at only three sites. We conclude that *R. muscosa* has disappeared from about half of its historical localities in Sequoia and Kings Canyon National Parks during the past three decades, and has been extirpated in some drainages. The magnitude of decline appears to be even more pronounced outside the parks. The causes for these declines are not clear.

During the past three decades, populations of many amphibian species have declined or disappeared throughout the world, including sites within some of the best preserved environments on earth (Barinaga, 1990; Wake, 1991). One example is *Rana muscosa* (mountain yellow-legged frog) in the Sierra Nevada of California and Nevada, which has disappeared from many locations within Yosemite, Sequoia, and Kings Canyon National Parks and several wilderness areas outside these parks. Most of these disappearances did not appear associated with obvious changes in the terrestrial environment or in patterns of land or recreational use.

The purpose of this study was to assess the extent to which *R. muscosa* populations have changed during the past several decades in Sequoia and Kings Canyon National Parks. The study focused on these parks because they include a large portion of the range of *R. muscosa* in the Sierra Nevada, and because both historical and recent records were available from other studies (Bradford, 1989; Bradford et al., 1993).

METHODS—Sequoia and Kings Canyon National Parks lie adjacent to one another along the western slope of the Sierra Nevada, and jointly comprise 3,498 km² (Fig. 1). The parks contain hundreds of lakes, meadows, and streams at high elevation (>2,500 m) in the headwaters of four major river systems (San Joaquin, Kings, Kaweah, and Kern) that flow into the San Joaquin Valley. Most of this land lies in wilderness areas, where use is restricted to recreational backcountry activities with access only by foot or pack animal. Historically throughout the Sierra Nevada, tadpoles and adults of *R. muscosa* were often abundant in ponds, lakes, meadows with permanent pools, and, to a lesser extent, streams above 2,000 m (Grinnell and Storer, 1924; Zweifel, 1955). However, the introduction of salmonid fishes between approximately 1870 and 1950 eliminated *R. muscosa* from many sites (Bradford, 1989; Bradford et al., 1993). Nevertheless, *R. muscosa* persisted in many sites where fish were not introduced.

Our study consisted of detailed resurveys of two areas within the parks, a park-wide assessment of status based on comparison of historical and recent records, and an assessment of status elsewhere in the Sierra Nevada, also based on a comparison of historical

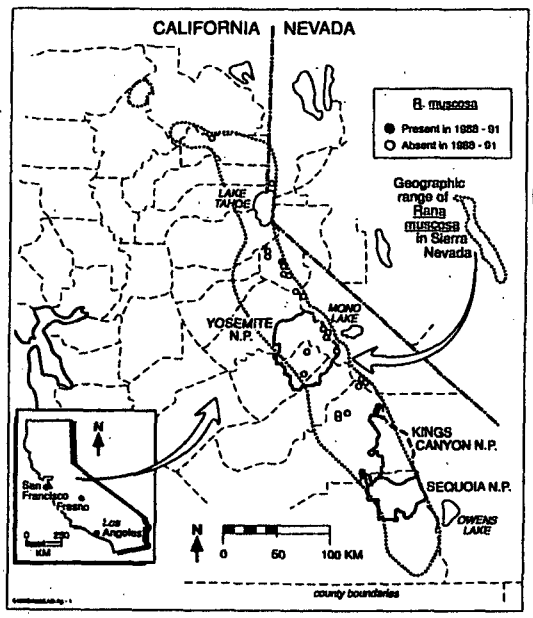

FIG. 1—Comparison of historical (1955 to 1979) and recent (1988 to 1991) records for *R. muscosa* outside of Sequoia and Kings Canyon National Parks. No two localities were less than 1 km apart. Historical geographic range is from Zweifel (1955).

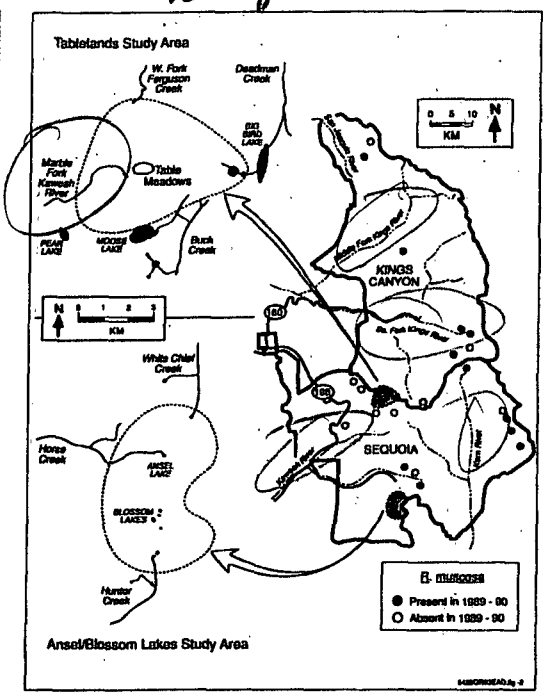

FIG. 2—Location of Tablelands and Ansel/Blossom Lakes study areas, and comparison of historical (1955 to 1979) and recent (1989 to 1990) records for *R. muscosa* within Sequoia and Kings Canyon National Parks. No two historical localities were less than 1 km apart.

and recent records. The detailed resurveys were conducted in the Tablelands and Ansel/Blossom Lakes areas (Fig. 2). In 1978–1979, 67 lakes and ponds in these two areas were surveyed for *R. muscosa*, *Pseudacris* (=*Hyla*) *regilla* (Pacific chorus frog), and fish (Bradford, 1989). In July and August 1989, we resurveyed 45 of these lakes and ponds, and two complexes of meadow pools by searching shoreline waters in the same manner as in 1978–1979. *Rana muscosa* and *P. regilla* were considered present if either tadpoles or frogs were found. Because of logistical constraints, we biased the resurveys towards sites where amphibians were previously present. The resurveyed sites encompassed nearly the entire original area, and included the headwaters of seven creek-system tributaries to the Kaweah or Kings Rivers (Fig. 2).

Although all resurveyed sites represented sites for frog reproduction, adults of *R. muscosa* may move between some sites that are close together. For this reason, we treated sites separated by <200 m and connected by a drainage channel as a single locality. We also excluded sites where fish were present in 1978–1979.

For the park-wide assessment of status of *R. muscosa*, we obtained historical records for the species from museums, literature, park records, and personal communications with several researchers. We selected records between 1955 and 1979 that were sufficiently precise to compare with park-wide surveys for amphibians conducted in 1989–1990 (Bradford et al., 1993). These years were chosen because relatively few accurate records were found for *R. muscosa* prior to 1955. None of the sites duplicated those in the Tablelands and Ansel/Blossom Lakes study areas.

For the assessment of status of *R. muscosa* elsewhere in the Sierra Nevada, we obtained historical records for *R. muscosa* between 1955 and 1979 from museums, literature, and personal communication with several researchers. Twenty-four sites were selected with sufficient precision to compare with recent surveys. Ten of the 24 were near sites that had been randomly selected for amphibian surveys in another study (Bradford et al., 1994), and they were surveyed in 1990–1991 as part of that study. The remaining 14 sites were resurveyed by several researchers during 1988–1991 (D. F. Bradford, pers. observ.; L. Cory, D. L. Martin, M. L. Morton, and E. P. Pister, pers. comm.).

RESULTS—In the two study areas resurveyed in 1989, 32 localities were visited that met the criteria of minimum distance between sites and

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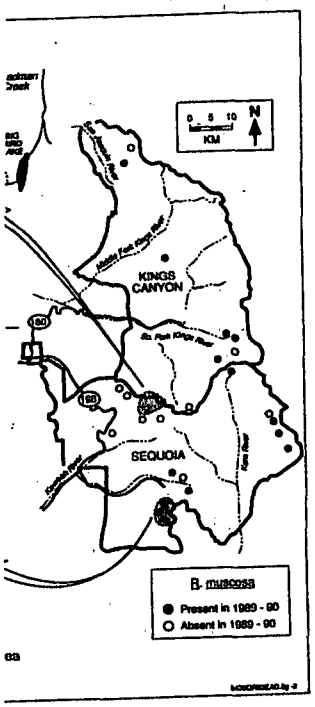

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absence of fish in 1978–1979. *Rana muscosa* occurred at 27 of these sites in 1978–1979, but was found at only one site in 1989 (Table 1). Moreover, it was absent in 1989 at all five sites where it was previously absent (Table 1). This change in abundance represents a significant change in both study areas ($P < 0.01$, Table 1). For the single site in which *R. muscosa* was found, Table Meadows, the population consisted of only late-staged tadpoles and recently metamorphosed frogs. No tadpoles or frogs were found during a recheck of this site in 1991, nor in this and 17 other Tablelands sites resurveyed again in 1993.

In contrast, the occurrence of *P. regilla* did not change significantly between 1978–1979 and 1989 in either survey area (Table 1; $P > 0.05$). Fish were present in two of the sites in the Ansel/Blossom Lakes in 1989 which formerly lacked fish. Both *R. muscosa* and *P. regilla* were present in these two sites in 1978–1979, but were absent in 1989.

In the park-wide assessment of status, records for only 21 sites were available for comparison between 1955–1979 and 1989–1990 (Fig. 2). Most of these sites were visited in the 1960s by L. Cory and H. Basey. Of the 21 sites, *R. muscosa* was found in only 11 in 1989–1990. Sites lacking the species appeared to be concentrated in the western portion of Sequoia National Park (Fig. 2).

In the assessment of status elsewhere in the Sierra Nevada, records for 24 sites were used for comparison between 1955–1979 and 1988–1991. These sites are scattered throughout the historical range of *R. muscosa* in the Sierra Nevada exclusive of Sequoia and Kings Canyon National Parks (Fig. 1), and range in elevation from 2,100 to 3,400 m. Of these 24 sites, 21 lacked the species during resurveys in 1988–1991, including four sites in Yosemite National Park (Fig. 1). With the exception of one site, none had undergone obvious changes in habitat.

TABLE 1—Results for 32 sites resurveyed for amphibians and fish in the Tablelands and Ansel/Blossom Lakes study areas in 1989. *P* values refer to McNemar's test for significance of changes (Siegel, 1956). ns = not significant at 0.05 level.

Presence–absence 1978–1979	1989 Present	1989 Absent	Total	*P*
Rana muscosa				
Tablelands				
Present	1	16	17	<0.001
Absent	0	4	4	
Total	1	20	21	
Ansel/Blossom Lakes				
Present	0	10	10	<0.01
Absent	0	1	1	
Total	0	11	11	
Pseudacris regilla				
Tablelands				
Present	8	0	8	ns
Absent	5	8	13	
Total	13	8	21	
Ansel/Blossom Lakes				
Present	3	4	7	ns
Absent	1	3	4	
Total	4	7	11	

DISCUSSION—Our data from within and outside of Sequoia and Kings Canyon National Parks indicate that *R. muscosa* has disappeared in recent decades from many areas. In the Tablelands and Ansel/Blossom Lakes study areas, the species has apparently disappeared from the headwaters of all seven creek systems involved, because all potential habitat upstream of fish-inhabited waters was included in the resurveys. Curiously, populations of *Pseudacris regilla* have not changed over the same time period. These extirpations of *R. muscosa* appear to be part of a pattern of disappearance of the species in the western portion of Sequoia National Park, which is drained primarily by the Kaweah River. Elsewhere in the two parks, the few scattered historical records suggest that the majority of historical populations have not disappeared (Fig. 2), and many populations were extant in 1989–1990 in the drainages of the Kern, Kings, and San Joaquin Rivers (Bradford et al., 1993). In contrast, outside of Sequoia and Kings Canyon National Parks, most historical populations appear to have been extirpated.

The causes for population disappearances of *R. muscosa* in Sequoia and Kings Canyon National Parks are not at all clear, nor is it evident whether such causes are natural or anthropogenic in origin. Mass mortality of *R. muscosa* has been reported. Hundreds of adults in one population died during the summer of 1979, apparently due to "red-leg" disease (Bradford, 1991). In the same population and year, the entire cohort of metamorphosing tadpoles was eliminated by predation

from Brewer blackbirds, *Euphagus cyanocephalus*, (Bradford, 1991). Disappearances of adults in many other populations were evident following the winter of 1977–1978, and these disappearances may have resulted from winterkill due to oxygen depletion (Bradford, 1983). However, this apparent winterkill may also have been disease-mediated. Recent die-offs of *Bufo boreas* in the Rocky Mountains and *B. canorus* in the Sierra Nevada were associated with "red-leg" disease, and appeared to have occurred primarily during winter (Carey, 1993; Sherman and Morton, 1993). Drought in the western U.S. from 1986 to the present did not appear to be a factor in the disappearances of *R. muscosa* because disappearances of some populations were evident prior to 1986, and the species inhabits primarily permanent waters (Zweifel, 1955; Mullaly and Cunningham, 1956).

Although the causes of population extirpations of *R. muscosa* may have been natural, they also may have been anthropogenic in origin. Carey (1993) speculated that some anthropogenic environmental stressor (or stressors) caused suppression of immune function that was exacerbated by low temperature in the montane environment, resulting in outbreaks of "red-leg" disease. Acidic deposition may be such an environmental stressor in the Sierra Nevada. However, recent studies in both the field and laboratory do not support the hypothesis that acidic deposition has been a factor in causing population declines of *R. muscosa* (Bradford et al., 1992; Bradford et al., 1994). Another anthropogenic factor is introduced fish. Brook char colonized two lakes in the Ansel/Blossom Lakes study areas in 1979 and 1989, and could account for the disappearance of both *R. muscosa* and *P. regilla* in these sites. However, fish did not colonize any of the other sites in the Ansel/Blossom Lakes or Tablelands areas, and could not have had a direct effect on the 25 other populations resurveyed for *R. muscosa*. Human activities probably have not changed much during the past 10 to 30 years. All sites are protected within the national parks, and many of the sites are remote from established trails. Inadvertent effects of amphibian researchers is a possibility in some sites surveyed in 1978–1979, such as by toe-clipping frogs in two populations or by introducing pathogens on nets (Bradford, 1983, 1984, 1989, 1991). However, research activity in most of the resurveyed sites in the Tablelands and Ansel/Blossom Lakes study areas involved no contact with animals or the water, and die-offs of adults in many of these populations occurred prior to the first visitation.

We argued elsewhere that population fragmentation has caused or contributed to population extinctions of *R. muscosa* (Bradford et al., 1993). Remaining populations were largely isolated from one another by introduced fishes in intervening waterways, and this degree of isolation differed by about tenfold from the condition prior to the introduction of fishes.

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