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LONG-TERM FLUCTUATIONS OF AN ISOLATED POPULATION OF THE PACIFIC CHORUS FROG (*PSEUDACRIS REGILLA*) IN NORTHWESTERN NEVADA

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ABSTRACT.—In 80% of the years between 1975 and 1989 chorus frogs were able to produce offspring that completed metamorphosis and became members of the next generation. During 3 of these 15 years (1975, 1983, and 1986), floods annihilated chorus frogs in the breeding pond. Between 1905 and 1989 this geographically isolated population of *Pseudacris regilla*, the Pacific chorus frog, located at the western edge of the Great Basin in northwestern Nevada, became reestablished after 10 natural physical disturbances including spring flash floods, numerous kill-offs by sudden drastic rises in water temperature, and stream dry-ups. Ninety percent of the frogs in this population were shades of green with black dorsal speckles and eyestripes. Predators were the belted kingfisher (*Megaceryle alcyon*), western terrestrial garter snake (*Thamnophis elegans*), and domestic house cat (*Felix domestica*).

Key words: Pacific chorus frog, Pseudacris regilla, *Great Basin, population reestablishment, coloration, chorus frog predators.*

Pseudacris regilla (= *Hyla regilla*), the Pacific chorus frog, is one of the most abundant and widespread amphibians in the northwestern Nevada portion of the Great Basin. Yet, no studies have been published on the chorus frog in this geographical area. Test (1898), Van Denburgh and Slevin (1921), and Cowles and Bogert (1936) reported that chorus frogs in southern Nevada were localized and not especially abundant. Linsdale (1940) recorded *P. regilla* populations in southern Nevada. Banta (1961) studied populations of *P. regilla* along the lower Colorado River in southeastern Nevada and assumed other established populations were exterminated by the rising waters of Lake Mojave. Outside the Great Basin, Brattstrom and Warren (1955) made observations on the ecology and behavior of the Pacific chorus frog in southern California. Jameson (1956, 1957) reported on the growth, dispersal, survival, population structure, and homing responses of the Pacific chorus frog in the Willamette Valley, Oregon. Whitney and Krebs (1975) studied the spacing and calling in Pacific chorus frogs at Marion Lake, British Columbia. Reynolds and Stephens (1984) reported on multiple ectopic limbs in a wild population of *P. regilla* near Boise, Idaho.

In recent years there has been much concern over the decline of populations of many amphibian species (Wake and Morowitz 1990); but as reported by Pechmann et al. (1991), supporting long-term census data are generally unavailable. This paper reports data on population fluctuations from 1905 to 1989 in an isolated population of the Pacific chorus frog in northwestern Nevada. This study shows the resilience of this species to natural physical disturbances and predation. In addition, it shows that *Pseudacris* populations show wider fluctuations, this in agreement with Pechmann et al. (1991) and Caldwell (1987). Also, it is in agreement with Bradford et al. (1992), who reported that *P. regilla* populations do not appear to be declining.

STUDY AREA

The study area is a semipermanent pond located 18 km south of Reno at an elevation of 1500 m. The pond, 21 m in length, varies from 1 m at one end to 9 m at the other. Depth ranges from 0.1 to 1.2 m. Vegetation in the pond includes common horsetail (*Equisetum arvense*), water cress (*Radicula nasturium-aquaticum*), sedges, grasses, and algae. Vegetation surrounding the pond includes pinyon-

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juniper on the north, east, and south sides of the canyon that contain the pond. To the west along the canyon are dense growths of Fremont cottonwood (*Populus fremonti*), black willow (*Salix nigra*), and white clover (*Trifolium repens*).

METHODS

From 1974 to 1989 censuses of chorus frogs in or near the pond were conducted on alternate evenings from 1600 to 2300 PST throughout the breeding season, which extended from February to April. During the remaining nine months of the year, periodic counts of adult frogs were made.

Each census was conducted from an observation site located 6 m from the pond. From this point the total number of frogs in or near the entire pond was counted. To increase the accuracy of the counts, the pond was divided into four regions: northeast, northwest, southeast, and southwest. Each census started with the northeast region. After all frogs were counted in this region, counts were then made in northwest, southeast, and southwest sections. To increase the accuracy of the counts, a spotlight and binoculars were used. The procedure used to conduct a census was the same each year of the study.

In addition to conducting annual population censuses, we also recorded life history information. For each year of the study the date was recorded for the following activities: entering pond, chorusing, mating, egg laying, hatching, exiting of adults, completion of metamorphosis, and exiting of juveniles.

Throughout the study, air temperature was recorded 1 m above the ground and 3 m north of the pond, and water temperature was taken at the center of the pond at a depth of 15 cm.

Information concerning the study area, pond, and chorus frogs from 1905 to 1978 was provided by Mrs. George Minor.

RESULTS

Migration to the Pond

Migration of chorus frogs to the pond was documented to 1905, and it probably occurred many years prior to that (Mrs. Minor personal communication).

Except for flood years, a few male chorus frogs migrated to the pond in late February from 1975 to 1989. These males produced a chorus that attracted other males. The number of males increased from a few in late February to an average of 25 in mid-March. From mid-March to late April the number of males decreased to fewer than 5. In addition to attracting males, the chorus appeared to attract females. The breeding population of males and females peaked in March (mean ± SD, 60 ± 3.8; range, 53–66; Fig. 1 and Table 1). Thus, chorus frogs migrated to the pond from late February to early May, and the male breeding chorus extended over a 3-month period.

Reproduction and Metamorphosis

Mating commenced soon after the frogs entered the pond and continued until early April. During this time no territorial disputes or fighting was observed. Egg laying occurred from mid-March to mid-May; eggs began to hatch into tadpoles in mid-April. The brownish black tadpoles tended to localize in the deeper (up to 1.2 m), downstream portion of the pond. Tadpoles and near-transformed individuals grew rapidly in the 12–18° C water, and by early October all frogs gradually exited the pond. From early October to February only an occasional chorus frog was seen or heard in the pond. The transformed individuals probably matured in one season and returned to the pond as fully grown adults the next year as shown by Jameson (1956).

Ninety percent of transformed adults were light to dark green with dorsal black speckles and black eye stripes. Brattstrom and Warren (1955) found that green and brown phases occurred in about equal numbers. Variations in color of *P. regilla* were not observed (Test 1898). Black eye stripes were always present as reported by Brattstrom and Warren (1955).

Periodically, from February to July 1986-1989, 10 light green *P. regilla* were kept in a brown aquarium, and within 1 h all individuals changed to a dark green phase. Even after 120 h no green frogs turned brown. Most dark green frogs turned a lighter green in an open aquarium. Captive chorus frogs were not kept after 5 days because they did not feed. These observations supported those of Brattstrom and Warren (1955) and Resnick and Jameson (1963), who reported that the primary green coloration and black eye stripes are genetically determined, while the color phases and

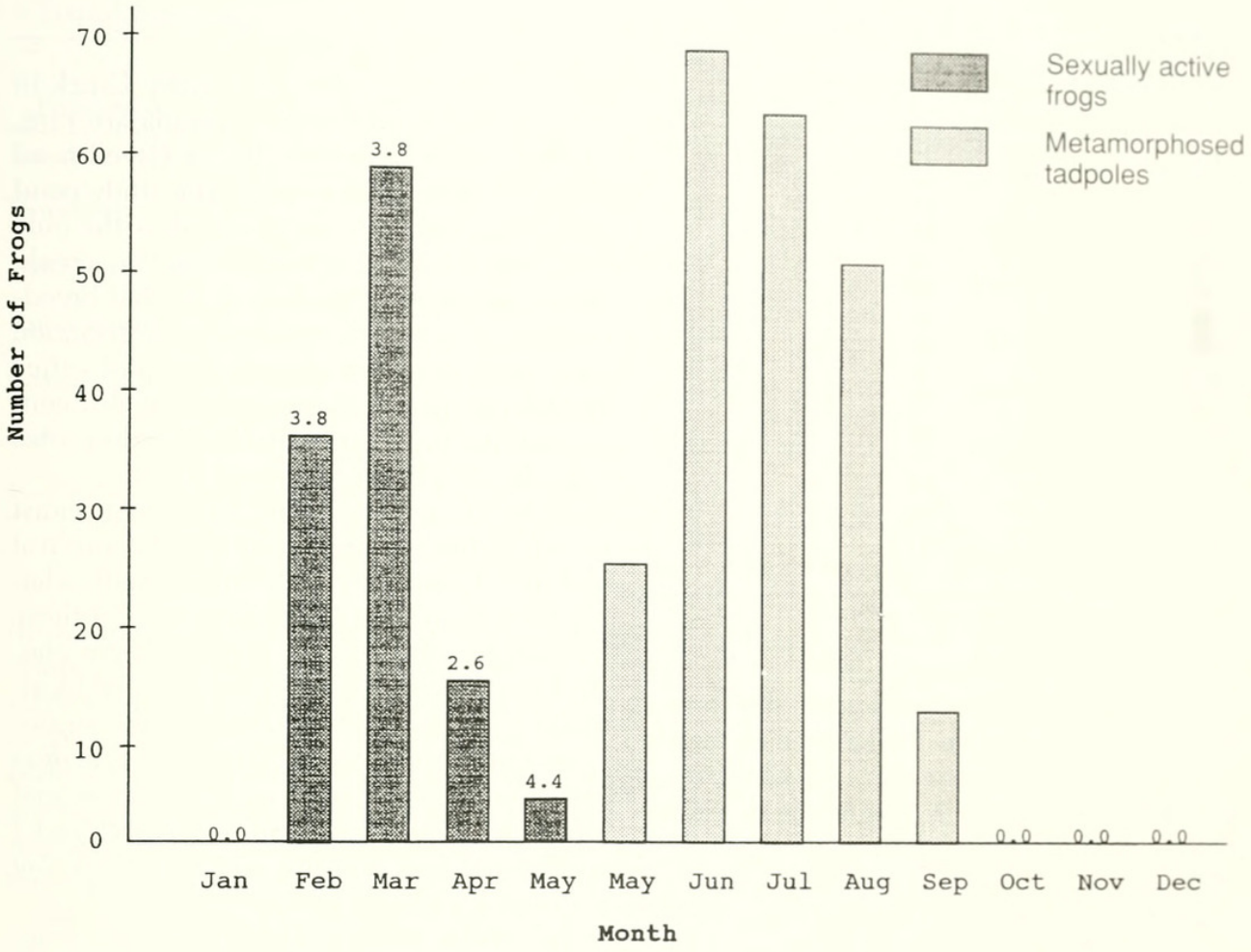

Fig. 1. Average number of frogs during each month for 12 of the 15 years (1974–1989). Counts were made at night. Top numbers are the standard deviations.

spots are environmentally regulated. Season, locality, and, to some extent, age also affect color (Resnick and Jameson 1963). Neither albinism described by Resnick and Jameson (1963) nor limb abnormalities reported by Reynolds and Stephens (1984) were observed in these populations of *P. regilla* during the 15 years of observation.

Natural Physical Disturbances

From 1905 to 1989 the chorus frog population in the breeding pond was annihilated 10 times. From 1975 to 1989, in 1975, 1983, and 1986, the time of this study, the chorus frog population in the pond was eliminated three times by flash floods. For 12 of these 15 years (80%), chorus frogs produced offspring that completed metamorphosis. Heavy rainfalls, along with melting snow at higher elevations, or prolonged downpours caused Bailey Creek to become a rushing torrent, rising up to 1 m above normal pond level. Twice during the study violent thunderstorms were observed, and they generated rapidly moving mudflows that scoured the streambed. In addition to flash flooding, sudden drastic rises in pond water temperature and drought conditions also reduced the chorus frog population in the pond. In six of the years, from 1974 to 1989, in March and April, the pond water temperature rose from 7° C to 24° C within 20 days. This sudden rise in pond water temperature had a negative impact on the chorus frog population for those years. In three of the years a light snowpack and sparse rainfall created drought conditions; both Bailey Creek and the pond dried up.

Predation

During the study three predatory species, the belted kingfisher (*Megaceryle alcyon*), western terrestrial garter snake (*Thamnophis elegans*), and domestic cat (*Felix domestica*), were observed taking chorus frogs.

The belted kingfisher preyed on both larvae and adults in the water. Throughout the

TABLE 1. Number of adult frogs during the study period, February–May 1975–1989.

Year	February	March	April	May
1975[a]	1	0	0	0
1976	36	55	19	11
1977	38	64	15	8
1978	37	61	17	2
1979	39	62	14	9
1980	31	53	10	12
1981	39	58	13	16
1982	35	56	15	5
1983[a]	1	4	0	0
1984	39	57	13	3
1985	45	60	16	8
1986[a]	2	0	0	0
1987	34	64	19	0
1988	31	66	17	8
1989	41	63	17	10
Mean ± SD	37 ± 3.8	60 ± 3.8	15 ± 2.6	8 ± 4.4

[a]Not used to determine mean and standard deviation.

study, except for those years when the chorus frog population was destroyed by flash flooding, observations were made of kingfishers preying on chorus frogs. Frequently two kingfishers, sometimes three, took prey between 0600 and 0830 PST from February to July. A kingfisher typically dove into the water from a willow branch over the pond, returned to a perch with a tadpole, and then swallowed the entire organism. After catching a frog, the kingfisher flew to a perch, bashed the frog against the limb on the left and right sides alternately, and then swallowed the dead frog.

On 20 occasions from 1974 to 1989 western terrestrial garter snakes were observed within 4 m of or in the pond. Often three to five snakes were counted at one time. Mrs. George Minor (personal communication) remembered western terrestrial garter snakes being very numerous in the canyon, especially near the pond. On 10 different occasions she remembered seeing snakes take chorus frogs while on the bank or near shore. Brattstrom and Warren (1955) and Jameson (1956) listed garter snakes as predators of *P. regilla.*

At various times during the study at least 20 domestic house cats were abandoned near the study site. On four occasions cats were observed capturing frogs while on the bank. After each instance one to three bitten, battered, and torn frogs were found. These frogs were never eaten; they were victims of the hunting, playing, and killing behavior characteristic of house cats.

DISCUSSION

Riparian habitats such as Bailey Creek in the desert of northwestern Nevada are rare. The nearest water site to Bailey Creek is an irrigation ditch 5000 m west. The study pond area associated with Bailey Creek is the only breeding site for *P. regilla* along this creek. This indicates the significant role that breeding sites play in determining the distribution and survival of the chorus frog and other amphibian species. Jameson (1956) also concluded that the distribution of breeding sites was a limiting factor for chorus frogs.

In addition to breeding sites, cool, moist microhabitats are significant for the survival and distribution of chorus frogs. Pacific chorus frogs have been found in several of these habitats in northwestern Nevada. Eight chorus frogs were observed under plywood located on a mudflat, 10 were noted inside an isolated concrete, boxlike structure that was once used to store water at a spring (several meters from other places of free water), and 2 were noted in a housing unit for valves that operated a sprinkler system.

At precise times of the year chorus frogs migrate to and from these isolated microhabitats. In the early spring of the year during the breeding season, migration is toward the breeding pond. After metamorphosis is completed at the breeding ponds, migration is away from the pond toward a cool, moist microhabitat. During this study the chorus frog population at the study site was annihilated

TABLE 2. Average daytime ambient and pond water temperatures. Ambient temperatures were recorded 1 m above the ground and 3 m north of the pond. Pond water temperatures were recorded at 15 cm at the center of the pond.

Month	Ambient $\bar{x}$ daytime temperature (°C)	$\bar{x}$ pond water temperature (°C)
January	4	4
February	7	7
March	11	12
April	13	12
May	16	12
June	19	16
July	23	16
August	24	19
September	19	12
October	19	11
November	11	5
December	3	2

TABLE 3. Frog activity associated with time of year and range of both ambient and water temperatures.

Frog activity	Time of year	Temperature range (°C)	
		Water	Air
Entered pond, chorusing, and mating	Late February–early April	7–11	7–11
Oviposition	Mid-march–mid-May	9–12	11–16
Hatching and tadpole development	Mid-April–early August	11–18	12–22
Exit of sexually active adults	Late April–early May	12	14
Completion of metamorphosis	Late May–late September	12–16	16–18
Exit of metamorphosed tadpoles	Late August–early October	10–18	20–24
Very few or no frogs in the pond	Early October–late February	7–10	7–20

three times. Yet, each time during the next year's breeding season (1976, 1984, and 1987) chorus frogs were present in numbers similar to those of other years at the study site. The likely explanation is that chorus frogs living in microhabitats in the vicinity of the study site migrated to the breeding pond the year after the population was annihilated.

In late February adult males located and entered the pond probably in response to a rise in ground, water, and air temperatures (Table 2). Brattstrom and Warren (1955) concluded that at 10° C frogs will go to the water to breed. It is significant to note that *P. regilla* preferred lower temperatures than other hylids. This preference for lower temperatures was demonstrated at this site in that the temperature at which the frogs go to the pond to breed (Table 3) is on the average 5° C colder than that reported by Brattstrom and Warren (1955). In this study no warm rains occurred in February to initiate the movement of males to the pond; however, Jameson (1956) believed the first warm rains and a rise of reproductive hormones cause adult males to move to breeding ponds.

This study indicates that males remain in the pond during the entire but short breeding season. Jameson (1957) suggested that males migrate to the pond, breed, exit, and are replaced by other males. Attempts by males to establish and defend territories, i.e., trill calls, butts, and wrestling bouts (Perrill 1984) and territorial compression as other frogs enter the pond (Whitney and Krebs 1975), were not observed.

Throughout the study the isolated population of the Pacific chorus frog was subjected to a variety of environmental resistance. Yet, it was never eliminated; clearly, it is well adapted to a habitat that is subjected to periodic natural physical disturbances such as heavy rains, flash floods, and droughts.

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