Discovery

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Water temperatures in a California Red-legged Frog breeding pond

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Abstract

The California Red-legged Frog (*Rana draytonii*) is a threatened species; thus, resource managers are faced with maintaining, and even creating, breeding habitat for the frog. The Mediterranean climate regime where the frog occurs can result in breeding site desiccation during the long dry summer—before larval metamorphosis occurs—which can be exacerbated in coastal areas where prevailing cool temperatures might slow tadpole development. Water temperature profiles were logged every three hours for six days at a coastal breeding pond. Despite mid-day maximal air temperatures that averaged about 14°C, solar radiation produced mid-day shallow-water temperatures approaching 30°C. These preliminary data hopefully will encourage further research on the topic, but in the meantime will assist resource managers to better understand frog behavior and existing recommendations for maintaining, improving, and developing frog breeding habitat.

Discovery

Despite the importance of water temperatures in understanding several important California Red-legged Frog behaviors, no empirical data are available on the topic. This report describes the use of data loggers to gather water temperature profiles, which demonstrates the potential for broader research on the topic. In addition, the preliminary results and discussion will assist resource managers to better understand and develop optimal management and restoration activities for the threatened frog.

Key Words

California Red-legged Frog; frog breeding; Mediterranean climate; *Rana draytonii*; water temperatures.

Introduction

The California Red-legged Frog (*Rana draytonii*) is federally listed as threatened (1), which has resulted in considerable concern for habitat protection and management (2). The current distribution of the frog extends from central California south to northern Baja California, west of the Sierra Nevada and southern deserts (3). This area is largely characterized by a Mediterranean climate, with cool and wet winters and warm and dry summers (4). Because of this relatively unusual climatic regime, the frogs normally breed for less than a four-week period from about December through March (5), when conditions are suitably wet. However, larvae (tadpoles) must metamorphose before summer conditions dry their habitat, especially where Mediterranean water regimes are unaltered and perennial water is rare.

It is well established that frog larvae development is temperature dependent, with warmer conditions speeding the time to metamorphosis (6). Many populations of the California Red-legged Frog occur along the central California coast, where winter and spring daytime air temperatures normally do not exceed about 22°C because of the prevailing winds off the cold Pacific Ocean (4). The coastal climatic conditions result in larvae development occurring when air temperatures are relatively cool, even through the summer months.

Figure 1. Stock pond (photo taken 12 May 2012, 1142 hrs) where water temperature profiles were taken, viewed from northeastern corner towards the southwest. Dam is located at right of image, with the spillway in lower right corner. Grassland pastures are to the left of the image, and coastal scrub to the right. Trampled edges of the pond by cattle (a bull is visible just beyond far shallow end of pond), and band of sedges in shallow water, are clearly visible, but the sparse pond weed inside the sedges is not visible because of surface water reflection. Note overcast marine layer, which was typical while temperature loggers were present (see Methods and Figure 2).

In order for resource managers to understand why frogs behave the way they do, and also to effectively maintain, restore, improve, and create aquatic habitats for frogs, managers need to understand the optimal temperatures for frogs in these habitats. Unfortunately, there are few relevant data available on water temperatures where California Red-legged Frogs occur. As a start to filling this information gap, and to encourage further research on the topic, I present and discuss preliminary data gathered from a series of temperature loggers in a frog breeding pond in coastal central California.

Methods

I used a perennial stock pond (Figure 1) located near the town of Cambria in coastal central California (35.536°, -121.071°). The pond was on a private cattle ranch about 1.5 km east of the seashore at about 150 m elevation. It was created several decades ago by damming a short and highly seasonal (annual) stream. The pond surface area was about 40 x 25 m and it was about 3 m deep near the dam. The pond was used daily as a source of water by free-range cattle, which have influenced the habitats in and around the pond. The pond was surrounded to the east with grassland pasture, and to the west with coastal scrub. In the pond, there was up to a 1 m band of open shallow water between the muddy and trampled shore and sparsely-growing sedges (*Carex* sp.). The sedges emerged about 25 cm above the water surface and formed a 1–2 m wide band around the pond. Beyond the sedges was a 1–2 m wide sparse band of floating pond weed (*Potamogeton* sp.), which then gave way to the deep central area of the pond, which was without vegetation (Figure 1).

During night eye-shine surveys of the pond during the winter (breeding season) from 2004 through 2012, I counted up to eight adult and juvenile Red-legged Frogs per survey. Pacific Chorus Frog (*Pseudacris regilla*) calling at night during winter was often deafening, and their larvae were abundant in the shallow water near shore, where Red-legged Frog larvae also were observed.

I programed eight iButton temperature loggers (Maxim Dallas Semiconductor model DS1921G-F5, accuracy of ±1°C) to record every three hours starting at 1500 hrs (±1 min) on 12 May 2012 through 1800 hrs on 18 May 2012 (Pacific daylight savings time). I dipped the iButtons in hot beeswax before deployment to prevent water damage to the electronics, and the loggers positioned near the surface of the water were shaded by a small float and hung about 2 cm below the water surface. I deployed three sets of loggers. One set was at the shallow (upstream) end of the pond at the interface between the sedges and pond weed, with a logger on the bottom (40 cm deep) and another below the water surface. Another set was at the dammed (downstream) end of the pond at the interface of open water next to the shore and sedges, with a logger on the bottom (30 cm) and another below the surface. The third set was in open deep water just outside a patch of pond weed at the dam end of the pond, with loggers on the bottom (120 cm), 50 cm below the water surface, and near the surface. A logger also was placed in a metal tin box (9 x 6 x 2 cm) painted matte black and floating about 2 cm above the surface of the water on a wood block in the middle of the pond. Black boxes simulate a "black body" and are used for base-line comparisons in studies of the thermal biology of animals (e.g., 7,8,9).

I downloaded ambient air temperatures from the weather station on the Norris Rancho Marino Reserve in Cambria (Western Regional Climate Center. Available at wrcc@dri.edu [Accessed 21 May 2010]) that were logged at the same time that the iButtons recorded temperatures. The weather station is located on the coastal terrace next to the ocean about 1.2 km west of the study pond. In general, the weather pattern during the study period was typical for spring: coastal fog prevailed during several nights and persisted until sunrise or mid-day (Figure 1), when conditions became sunny and breezy, but remained cool (Figure 2).

Results

The mean (n=6) maximal water temperatures near the surface and on the bottom at the shallow end were 27.6°C and 21.6°C, and at the dam end were 26.1°C and 22.3°C. The mean maximal temperatures near the surface, 50 cm deep, and on the bottom at mid-pond were 23.9°C, 19.8°C, and 18.3°C, respectively. These were all warmer than the maximal mean ambient air temperature of 13.9°C at the weather station (Figure 2). The temperature profiles at each end of the pond in shallow water were very similar, so for clarity I have not graphed the data for the set of loggers at the dam end of the pond (Figure 2).

The daily temperature cycle is clearly distinguished in Figure 2, with some variation between days in the duration of minimal and maximal air temperatures, presumably due largely to changes in overcast conditions. Less pronounced, but similar, variation in the water temperatures were likely due to thermal inertia of water. Deeper water temperature maxima, compared to surface data, were lower and temporally delayed and prolonged. For example, all the maxima for the shallow surface temperatures occurred at 1500 hrs, whereas on the bottom the maxima were at 1800 hrs. The reduced maxima in mid-pond on the bottom lasted for up to six hours—well after the sun had set (Figure 2).

While deploying and checking the loggers, on three days I counted 4–5 adult Red-legged Frogs floating with their noses and eyes protruding through the surface of the water and pond weed, where the water was likely approaching 30°C during mid-day (Figure 2). These shallow areas also were where I invariably spotted frogs during past night surveys. While the loggers were in the pond, I also observed hundreds of Pacific Chorus Frog tadpoles in the warm water near shore in the vegetated areas.

Discussion

Water temperatures did not closely follow ambient (weather station) air temperatures because of the way solar radiation interacted with the large volume of water in the pond, which behaved similar to the black box just above the surface. Indeed, the near-surface water temperature profiles during daylight were similar to those of the black box, but in the absence of solar

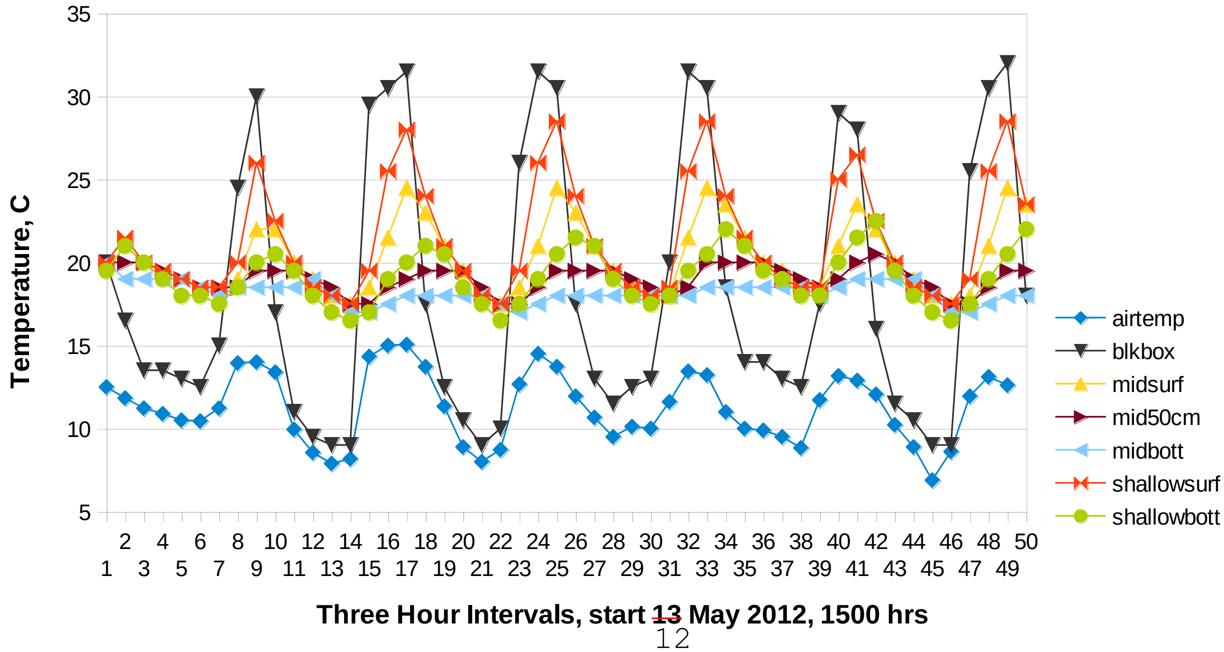

Figure 2. Temperature profiles during six days at a coastal California Red-legged Frog breeding pond. Abbreviations in key: airtemp = air temperatures recorded at the Norris Rancho Marino Reserve weather station; blkbox = air temperatures recorded mid-pond in a black tin above surface of pond; midsurf = surface water temperatures mid-pond; mid50cm = water temperatures mid-pond 50 cm below surface; midbott = water temperatures mid-pond on bottom; shallowsurf = surface water temperatures at shallow end of pond; shallowbott = bottom water temperatures at shallow end of pond. Note that the iButton logger "midsurf" started recording temperatures seven 3-hour periods after the others, which were all started on 12 May 2012 at 1500 hrs (20° ±1.0°C). Time is Pacific daylight savings.

radiation at night the similarity disappeared, with the black box and air temperatures becoming more similar. None of the water temperatures at night closely matched the extremes of the black box or ambient air temperatures (Figure 2) because of the thermal inertia of the pond water. Because of the properties of black bodies, and the relatively large amount of water in ponds that support California Red-legged Frog populations, it is unlikely that these ponds would become too warm for the frogs. However, it is likely that without the impacts of cattle on vegetation, ponds would become deeply shaded by trees and shrubs on shore and dense emergent vegetation in the shallow water, resulting in less solar radiation reaching the water and lower water temperatures, perhaps similar to logged temperatures at the pond when the sun was not high in the sky (Figure 2).

Frogs are poikilothermic (10) and several physiological features, and reproduction, are influenced by temperature. Warmer water, as heated by solar radiation, results in a shorter time between oviposition and metamorphosis (6)—a feature that would be highly adaptive in a Mediterranean climate because of the potential for aquatic conditions at breeding sites to be short-lived. The movements of some adult frogs (11,12, 13) may be related to seeking breeding sites with optimal water temperatures. The most dramatic movements can be nearly 3 km one way, which represents a considerable survival risk for migrating adults (11) that may reflect the importance of water temperatures for successful reproduction in some areas. The use of optimal breeding sites also may partially explain the remarkable homing of up to nearly 3 km by some translocated adult California Red-legged Frogs (14,15). If warm water is limited—possibly resulting in a prolonged period of larval development—and the breeding site is perennial, then over-wintering larvae might be found (16).

Historically, suitable frog breeding sites probably were found mostly in unaltered low-gradient annual creeks (17), with perennial creeks and ponds probably being rare in the Mediterranean climate. However, many of these sites are now negatively impacted by altered water regimes (water extraction and damming), and sometimes entirely eliminated by urban and agricultural development. Counteracting the loss of natural habitats for California Red-legged Frogs is the proliferation of perennial ponds associated with the introduction of livestock. More recently, ponds are being restored or built specifically for the benefit of frogs.

However, for these ponds to support breeding populations of frogs, they should be suitably configured, constructed, and maintained (Appendix D in 2, updated by Scott, N.J. and G.B. Rathbun. 2009. Management Guidelines for the California Red-legged Frog. Available from http://www.elkhornsloughctp.org/training/show_train_detail.php?TRAIN_ID=CaY53SF [Accessed on 19 May 2012]). In some areas, pond management may need to include features conducive to creating warm water habitats, as were present in the stock pond I monitored, and recommended by Scott and Rathbun (2009. *op*. *cit*.).

My results show that it would be relatively easy to temporally and spatially expand this preliminary research to include replication in different ponds with slightly different ambient air temperature regimes and shade conditions, as well as during different times of year. It is likely that with additional data, further insights into the life history of the California Red-legged Frog, and its management, would be gained.

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