BIOLOGY OF THE CALIFORNIA RED-LEGGED FROG: A SYNOPSIS

DAVID COOK, Biology Department, Sonoma State University, 1801 E. Cotati Avenue, Rohnert Park, CA 94928, USA

Key words: behavior, conservation, ecology, *Rana aurora draytonii*, Red-legged frog

1997 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 33:79-82

Many species of frogs and toads in western North America, and in particular California, have shown substantial population declines (Nussbaum et al. 1983:157-161, Hayes and Jennings 1986, Jennings 1988, Drost and Fellers 1996, Fisher and Shaffer 1996). In California, the collapse of the native amphibian fauna is of concern. For example, the California Department of Fish and Game has listed all 8 in the genus *Rana* native to the state as Species of Special Concern (Jennings and Hayes 1994). One such taxon is the California red-legged frog (*Rana aurora draytonii*), which was listed under the Federal Endangered Species Act as threatened in 1996 because of marked decline or extirpation throughout nearly all of its range (Federal Register 1996). Knowledge of the available information on the red-legged frog is important in conservation and recovery efforts, as well as in directing further research. Here I review existing behavioral and ecological studies, anecdotal information, and unpublished data from expert herpetologists on the California red-legged frog.

DISTRIBUTION AND DESCRIPTION

The red-legged frog historically ranged from southwestern Canada to northwestern Baja, Mexico from sea level to about 1,500m (Jennings and Hayes 1994). Two subspecies are recognized. The northern red-legged frog (*Rana aurora aurora*) ranges from Marin County (Hayes and Jennings 1986), located just north of San Francisco, along coastal drainages into Canada. The California red-legged frog (*Rana aurora draytonii*) historically occurred throughout the foothills of the Central Valley and coastal drainages from Marin County to Baja, Mexico. The 2 subspecies share a contact zone from Marin County to Del Norte County (Hayes and Kremples 1986) and have behavioral, morphological, geographic, and biochemical differences that may warrant their consideration as separate species (Green 1985, Hayes and Miyamoto 1984).

Most remaining populations of the California red-legged frog are restricted to coastal watersheds from the San Francisco Bay area to Ventura County (Jennings and Hayes 1994). Populations in the western Sierra Nevada and southern California have been nearly extirpated. Recent field studies have identified a few locations with red-legged frogs in the Sierra Nevada (G. Fellers, Pt. Reyes National Shoreline, and S. Barry, Univ. Calif. Davis, pers. comm.) and northern Baja (L. Grismer, La Sierra University, pers. comm.). There is 1 extant record from the Santa Rosa Plateau, Riverside Co. (M. R. Jennings, California Academy of Sciences, pers. comm.).

The red-legged frog is the largest frog native to California and can be identified by skin coloration and form. Adult frogs are sexually dimorphic, with females being substantially larger than males. Males range from 78 to 116 mm in body length, while females are larger and range from 87 to 138 mm (Hayes and Miyamoto 1984).

Red-legged frogs become sexually mature at an age of 2-4 years, with females requiring longer to develop. The dorsal side of the frog is brown or reddish brown to dark brown with dark brown to black spots. Some frogs lack red pigment on the ventral side almost entirely, but red is usually present on the under surface of the lower belly, thighs, legs, and feet. The intensity of red skin color is highly variable. A key identifying feature within the range of the taxon is the presence of dorsolateral skin folds that run from the back of the eye to the posterior end. Adult male frogs can be identified by the presence of swollen thumps (nuptial pads) used in breeding.

The red-legged frog inhabits streams and marshes. Stream habitats are typically small pools with overhanging vegetation, such as willow (*Salix* spp.). In marshes, cattail (*Typha* spp.) and bulrush (*Scirpus* spp.) are a common habitat component. For further discussion of habitat requirements see Hayes and Jennings (1988).

BREEDING AND FORAGING BEHAVIOR

Adult red-legged frogs are primarily aquatic and are most active during the night, although the use of terrestrial habitats is important. Upland habitats may be used for dispersal by adult and juvenile frogs to other aquatic habitats, escape habitat during flood events, and aestivation. Like most species of frog, red-legged frogs are opportunistic feeders and will eat nearly any animal prey that can be swallowed. Prey size varies, but larger frogs are capable of taking larger prey (Hayes and Tennent 1985). A captive frog was reported to have swallowed a western toad two-thirds its own body size (Hays 1955). Red-legged frog foraging consists of waiting at the water's surface for prey to come close enough to attack. Frogs are directed toward prey by movement but discriminate poorly among prey types (Hayes and Tennent 1985).

Prey items vary from location and by season but typical invertebrates taken include beetles (*Coleoptera*), water striders (*Hemiptera*), spiders (*Arachnida*), snails (*Mollusca*), and sowbugs (*Armadillidium vulgare*). Larger vertebrate prey may include Pacific treefrogs (*Hyla regilla*) and possibly mice (*Peromyscus californicus*) (Hayes and Tennent 1985).

It is not known exactly what triggers breeding in the red-legged frog, but this behavior is probably influenced by local precipitation and ambient temperature. Breeding occurs from late November to late April (Hayes and Jennings 1986). The start of breeding can fluctuate by year and location (author's pers. obs.). Frogs typically breed after significant rainfall and after the cold periods of winter have passed. During the 1996-97 winter season at Pt. Reyes, located along the coast north of San Francisco where the climate is moderate, frogs began breeding in early December (K. Freel, Pt. Reyes National Shoreline, pers. comm.), and 30 km inland from the coast frogs at Ledson marsh located in Annadel State Park, Sonoma Co., began breeding in mid-January (author's pers. obs.). Freezing temperatures occur more frequently at Ledson and this may be responsible for the time difference in breeding between coastal and inland populations, although other factors may be involved. During the drought of 1992, the Ledson population did not breed until late March (P. Northen, Sonoma State Univ., unpubl. data).

Red-legged frog breeding and egg mass deposition typically occur within a 2-4 week period. Male frogs produce advertisement calls to attract females. Choruses of 3-12 male frogs form at breeding sites prior to arrival of females. Evening choruses may last a month or more (author's pers. obs.). Calls are a low, 3-7 noted guttural sound sometimes ending with a groan (Stebbins 1985: 82-83). Red-legged frog vocalizations do not travel far in the field and can be heard for about 30 m. At breeding sites, one or a few red-legged frog vocalizations are typically heard among a large chorus of Pacific treefrogs. Occasionally, red-legged frog calls can be heard during the day (author's pers. obs.). The purpose of diurnal calling is not known. After a female selects her mate the pair moves in amplexus to the oviposition site. At Ledson Marsh, frogs use traditional breeding sites year after year, and egg laying occurs in or near the location of male choruses (author's unpubl. data).

LIFE HISTORY

Eggs are laid in a loose, gelatinous mass on the surface of the water attached to emergent vegetation. In lentic habitats, eggs may not be anchored. An egg mass can contain several hundred (author's pers. obs.) to 6,000 eggs (Jennings and Hayes 1994). Newly deposited masses have a blue hue and are often easy to see in the field. Later, egg masses are often covered with silt or algae and can be cryptic.

Eggs are laid in cold water typically less than 16° C (Jennings 1988). *R. a. draytonii* embryos probably have similar temperature requirements to the related *R. a. aurora*, which has a critical thermal maximum of 21° C (Nussbaum et al. 1983:157-161). This intolerance of high temperatures is an important factor related to the red-legged frog's early breeding season. The red-legged frog has a low tolerance for salinity, which may be a source of mortality in coastal populations with tidal influence. The maximum salinity tolerance of adult frogs is about 9 parts per 1000 and embryos do not survive at concentrations greater than 6 parts per 1000 (Jennings and Hayes 1990). Embryos hatch in 1-4 weeks depending on water temperatures, and newly hatched tadpoles are less than 1 cm in length.

The aquatic larvae, or tadpoles, are bottom dwellers and are usually concealed by emergent vegetation. Little is known about the ecology of tadpoles but they are thought to be algae grazers (Jennings and Hayes 1994). Red-legged frog tadpoles metamorphose within 3-5 months, usually from July through September. This is an important adaptation to California's Mediterranean climate, where ephemeral water bodies hydrate in the winter and are dry by late summer or early fall.

Following metamorphosis, juvenile red-legged frogs are semi-terrestrial and can often be seen basking on sunny days on banks or in shallow water near emergent vegetation. The survival rate of the red-legged frog is lowest during the early developmental stages. Survival rates from egg to juvenile frog are probably 1-5% (Calef 1973, Licht 1974, M. R. Jennings, California Academy of Sciences, pers. comm.).

FACTORS INFLUENCING THE DECLINE OF FROGS

Many factors have influenced the decline of the red-legged frog. Most of the following hypotheses I present are from studies by M.R. Jennings and M.P. Hayes. The primary factors suspected of having major impacts on red-legged frog populations are predation by the introduced bullfrog (*Rana catesbeiana*) and predatory fishes, such as sunfish (*Lepomis* sp.), and habitat alteration.

Other hypotheses for decline include overharvest of frogs, air and water pollution, solar radiation, pathogens and parasites, and mortality due to catastrophe. Commercial harvesting and over-exploitation of the red-legged frog occurred during the turn of this century (Jennings and Hayes 1985). Chemical pollutants, such as pesticides, may be a major factor in frog declines in the Sierra Nevada (Drost and Fellers 1996). Blaustein et al. (1996) showed that *R. aurora* eggs have a high hatching success regardless of ultraviolet radiation levels. Little direct information on the remaining reasons for decline is available.

Many factors likely have synergistic effects and have confounded the study of particular causes. Habitat alteration includes the physical removal of vegetation and change in hydrology. Loss of vegetation reduces escape cover for frogs, eliminates attachment sites for egg masses, and increases water temperature from solar exposure.

The bullfrog has been implicated as a predator and competitor of the red-legged frog, and other exotic species may have negative effects. Predation on red-legged frog juveniles (Twedt 1993) and tadpoles by bullfrogs has been reported (Kiesecker and Blaustein 1997, author's unpubl. data). In an experimental study, S. Lawler (Univ. Calif. Davis Department of Entomology, unpubl. data) showed that bullfrog tadpoles reduced the survival of red-legged frog tadpoles to less than 5% and suggested that competition was the reason. She also showed that mosquitofish (*Gambusia affinis*) injured and reduced the growth of tadpoles but did not affect their survival rate. Exotic crayfish (*Procambarus clarkii*) may prey on eggs. Gamradt and Kats (1996) showed that crayfish preyed on California newt eggs (*Taricha torosa*) by tearing through their tough, gelatinous capsule to eat the embryos. Red-legged frog eggs have a much softer casing around the embryo. The intensity and long-term effects of predation are not known. Further research on quantifying the effects of predation by exotic species would be useful.

Researchers have suggested that habitat alteration, such as damming an intermittent stream creating a permanent, warm-water habitat, favors the establishment of bullfrogs and fish to the detriment of the red-legged frog. Most remaining red-legged frog populations occur in ephemeral habitats without bullfrogs (Hayes and Jennings 1988). However, some of the largest remaining populations of red-legged frog appear to co-occur with the bullfrog. Examples include Pescadaro Marsh, Ledson Marsh, and several ponds in Pt. Reyes. The relationships of local climatic conditions, ephemeral nature of the water bodies, and rate of predation by one species on the other are probably important factors in the coexistence of the red-legged frog and bullfrog at these sites.

Ephemeral habitats eliminate the presence of fish and reduce the reproductive success of the bullfrog. The bullfrog is adapted to permanent warm-water habitats and has a late breeding period. Tadpoles often require a year or more to metamorphose, but under favorable conditions they can metamorphose within a year. For example, Ledson Marsh is ephemeral and has a population of both red-legged frogs and bullfrogs. When fully hydrated, the marsh is about 20 ha in size but by fall it is dry. By mid-October of 1996, the wetted area of the marsh was reduced to 1 small pool (< 0.1 ha); a week later the marsh was completely dry. Only a few bullfrogs were able to metamorphose and survive this dry period. In coastal areas, the red-legged frog and bullfrog do occur in permanent ponds, and year-round cool temperatures may be a key factor in reducing bullfrog reproductive success. Both species of frog occur at created ponds in Pt. Reyes, located at the northern coastal range of the taxon.

Future conservation-oriented research on the red-legged frog would be best directed toward its habitat requirements and predatory relationships with exotic species. Little is known about terrestrial habitat requirements of the red-legged frog for aestivation and dispersal. Further research in this arena is essential for the proper management of required aquatic and upland habitats. Long-term studies would provide important information on distinguishing between natural population fluctuates and anthropogentic effects. Also, experimental field studies are essential in differentiating between confounding factors. Finally, the bullfrog is naturalized in the state, and directing research efforts in determining the conditions that allow for the coexistence of both species of frog is a practical approach to conserving the red-legged frog.

ACKNOWLEDGMENTS

I thank Dr. Philip Northen, Sonoma State University, for collaborating on this paper, and Mark Jennings, Gary Fellers, Kathleen Freel, Sharon Lawler, and Sean Barry for contributing their field knowledge and expertise.

LITERATURE CITED

Blaustein, A. R., P. D. Hoffman, J. M. Kiesecker, and J. B. Hays. 1996. DNA repair activity and resistance to solar UV-B radiation in eggs of the red-legged frog. Conservation Biology 10:1398-1402.

Calef, G. W. 1973. Natural mortality of tadpoles in a population of *Rana aurora*. Ecology 54:741-758.

Drost, C. A., and G. M. Fellers. 1996. Collapse of a regional frog fauna in the Yosemite area of the California Sierra Nevada, USA. Conservation Biology 10:414-425.

Federal Register. 1996. Endangered and threatened wildlife and plants: determination of threatened status for the California red-legged frog. 61:25813-25833.

Green, D. M. 1985. Differentiation in amount of centromeric heterochromatin between subspecies of the red-legged frog, *Rana aurora*. Copeia 1985:1070-1074.

Fisher, R. N., and H. B. Shaffer. 1996. The decline of amphibians in California's Great Central Valley. Conservation Biology 10:1387-1397.

Gamradt, S.C. and L. B. Kats. 1996. Effect of introduced crayfish and mosquitofish on California newts. Conservation Biology 10:1155-1162.

Hayes, M. P., and M. M. Miyamoto. 1984. Biochemical, behavioral and body size differences between *Rana aurora aurora* and *R. a. draytonii*. Copeia 1984:1018-1022.

_____., and R. Tennent. 1985. Diet and feeding behavior or the California red-legged frog, *Rana aurora draytonii* (Ranidae). Southwestern Naturalist 30:601-605.

_____, and M. R. Jennings. 1986. Decline of ranid frog species in western North America: are bullfrogs (*Rana catesbeiana*) responsible? Journal of Herpetology 20:490-509.

_____, and D. M. Kremples. 1986. Vocal sac variation among frogs of the genus *Rana* from Western North America. Copeia 1986:927-36.

_____, and M. R. Jennings. 1988. Habitat correlates of distribution of the California red-legged frog (*Rana aurora draytonii*) and the foothill yellow-legged frog (*Rana boylii*): implications for management. Pages 144-158. USDA Forest Service Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-166.

_____. 1955. Ultragulosity in the frog *Rana aurora draytoni*. Herpetologica 11:153. Jennings, M. R. 1988. Natural history and decline of native Ranids in California. Pages 61-72 *in* H. F. De Lisle, P. B. Brown, B. Kaufman, and B. M. McGurty (eds.). Special Publication No. 4. Southwestern Herpetologists Society.

Jennings, M. R., and M. P. Hayes. 1985. Pre-1900 overharvest of California red-legged frog (*Rana aurora draytonii*): the inducement for bullfrog (*Rana catesbeiana*) introduction. Herpetologica 4:94-103.

_____, and _____. 1990. Status of the California red-legged frog *Rana aurora draytonii* in the Pescadero Marsh Natural Preserve. Sacramento: California Department of Parks and Recreation, Resource Division, Natural Heritage Section. 30pp.

_____, and _____. 1994. Amphibian and reptile species of special concern in California. Rancho Cordova: California Department of Fish and Game, Inland Fisheries Division.

Kiesecker, J. M. and A. R. Blaustein. 1997. Population differences in responses of red-legged frogs (*Rana aurora*) to introduced bullfrogs. Ecology 78:1752-1760.

Licht, L. E. 1974. Survival of embryos, tadpoles, and adults of the frogs *Rana aurora aurora* and *Rana pretiosa pretiosa* sympatric in southwestern British Columbia. Canadian Journal of Zoology 52:613-627.

Nussbaum, R. A., E. D. Brodie Jr., and R. M. Storm. 1983. Amphibians and reptiles of the Pacific Northwest: University Press of Idaho. 157-161pp.

Stebbins, R. C. 1985. A field guide to western reptiles and amphibians. Second edition. Boston: Houghton Mifflin Company. 336pp.

Twedt, B. 1993. A comparative ecology of *Rana aurora aurora* (Baird and Girard) and *Rana catesbeiana* (Shaw) at Freshwater Lagoon, Humboldt County, California. M.A. Thesis, Humboldt State University, Arcata, California. 59pp.