**MANAGEMENT GUIDELINES FOR THE CALIFORNIA RED-LEGGED FROG**

The California red-legged frog (*Rana draytonii*) is federally listed as threatened, thus there is a mandate to protect the frog and its habitat. However, an understanding of the biology of the frog is needed in order to develop effective strategies for managing the activities of people that impact the frog and its habitat.

We have assembled here three documents that will assist biologists in gaining some familiarity with the physical and ecological factors that we believe are important to the frog. These documents are the result of consulting the red-legged frog literature, interacting with our colleagues, and our 15 years of field experience working with the frog. We have also drawn on our interactions with the participants of the red-legged frog workshops that we have presented over the last ten years.

There is no substitute for reading the published literature. The attached annotated bibliography includes papers that we believe are most relevant to developing management actions for the frog. This list is an abridged version of the complete bibliography that we maintain on red-legged frogs, and it does not include many publications on other species that might be relevant, except that they do not directly address California red-legged frogs.

We believe that reproduction is the most important aspect of red-legged frog biology that is amenable to active management. This includes breeding habitat, as well as improving the survivorship of egg masses and tadpoles. We have developed a scoring scheme for grading habitats in terms of their suitability as breeding sites. The various factors that contribute to successful reproduction and population maintenance will be better understood through this document.

Lastly, we include an updated version of a pond management document that we originally prepared for the California red-legged frog Recovery Plan that was assembled by the U.S. Fish and Wildlife Service. This essay outlines some of the factors that should be addressed in building, modifying, or maintaining stock ponds for the benefit of red-legged frogs. Many of the recommendations in this document have been successfully implemented on the Los Vaqueros Reservoir and Watershed, which is part of the Contra Costa Water District.

The information in these three documents should contribute to biologists' abilities to develop and implement effective management schemes. At the same time, it should also become evident that broad-based management protocols will not be applicable across the entire range of the California red-legged frog. and most sites will require site-specific solutions to management issues.

26 February 2009

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**SELECTED AND ANNOTATED BIBLIOGRAPHY**

**OF THE BIOLOGY AND MANAGEMENT**

**OF THE CALIFORNIA RED-LEGGED FROG**

**(*RANA DRAYTONII*)**

This bibliography is selected to provide the literature most needed by professionals managing or consulting on projects that involve *Rana draytonii* and its habitat.

**1. Alvarez, J.A., C. Dunn and A.F. Zuur. 2004. Response of California red-legged frogs to removal of non-native fish. 2002-2003 Transactions of the Western Section of the Wildlife Society 38/39:9-12.**

Six ponds with exotic fish had little use by adult red-legged frogs and almost no successful reproduction. After the fish were removed, frog reproduction was successful, with counts up to 650 juvenile frogs in a single pond.

**2. Bland, D. 2006. Relocations of California red-legged frogs, California, USA. Re-introduction News, Newsletter of the Re-introduction Specialist Group, IUCN, No. 25:12-13.**

Nine frogs were re-located into nearby ponds when their ponds were to be subject to sediment removal. They were radio-tracked for two months. Four remained in the new habitat for at least 1 month. Two frogs returned to their ponds of origin, and 3 others ended up in dense cover in a direction towards their original ponds.

**3. Bridges, C.M. and R.D. Semlitsch. 2000. Variation in pesticide tolerance of tadpoles among and within species of Ranidae and patterns of amphibian decline. Conservation Biology 14:1490-1499.**

*Rana a. draytonii* and *R. pretiosa* tadpoles showed a higher tolerance of the pesticide carbaryl than other species of *Rana* tested.

**4. Bulger, J.B., N.J. Scott Jr. and R.B. Seymour. 2003. Terrestrial activity and conservation of adult California red-legged frogs *Rana aurora draytonii* in coastal forests and grasslands. Biological Conservation 110:85-95.**

Study of seasonal movements of radio-tagged frogs in the Santa Cruz Mountains, California. Documents winter and summer habitats and seasonal movements by 11-22% of adult population, most moving in a direct line rather than by following habitat corridors.

**5. Bury, R.B. and J.A. Whelan. 1984. Ecology and management of the bullfrog. U.S. Fish and Wildlife Service Resource Publication 155. 23 pp.**

Summary of bullfrog biology and management.

**6. Christopher, S.V. 2004. Introduced predator effects on a threatened anuran. Ph.D. Dissertation, University of California, Santa Barbara. 356 pp.**

In experimental and correlative studies, introduced fishes had stronger negative effects on *Rana a. draytonii* tadpoles and populations than bullfrogs or crayfish. Red-legged frog populations that coexisted in the study area with introduced predators are probably maintained by immigration from nearby sources that are free of the predators.

**7. Cook, D. 1997. Microhabitat use and reproductive success of the California red-legged frog (*Rana aurora draytonii*) and bullfrog (*Rana catesbeiana*) in an ephemeral marsh. M.S. Thesis, Sonoma State University, California. 47 pp.**

Habitat preferences in Ledson Marsh, Sonoma County changed with changes in the vegetation and water levels during the year. Dead spikerush in shallow water (mean=39 cm)was important early in the year, and flooded smartweed dominated in the summer and fall. Frogs tended to avoid open water and bulrush cover. There was a 2-month gap between red-legged frog and bullfrog breeding seasons and bullfrog oviposition sites were in deeper water (mean=63 cm vs. 33 cm for red-legged frogs).

The marsh is typically dry by fall, seriously limiting survival of bullfrog tadpoles. Survivorship from eggs to metamorphosis was estimated at 1.9% for red-legged tadpoles and 0.0001% for bullfrogs.

**8. Cook, D.G. and M.R. Jennings. 2007. Microhabitat use of the California red-legged frog (*Rana draytonii*) and introduced bullfrog (*Rana catesbeiana*) in a seasonal marsh. Herpetologica 63:430-440.**

Published version of Cook (1997).

**9. Corben, C. and G.M. Fellers. 2001. A technique for detecting eyeshine of amphibians and reptiles. Herpetological Review 32(2): 89-91.**

Evaluates the lighting equipment available for nocturnal frog surveys, and suggests using a light in combination with binoculars.

**10. D'Amore A., V. Hemingway and K. Wasson. 2009. Do a threatened native amphibian and its invasive congener differ in response to human alteration of the landscape? Biological Invasions, preprint, 6 Feb. 2009, doi : 10.1007/s10530-009-9438-z.**

A comparison of the different habitat correlates of sympatric bullfrogs and *R. draytonii* in an agricultural landscape. Several human-mediated factors favor bullfrogs.

**11. Davidson, C. 1995. Frog and toad calls of the Pacific Coast: Vanishing voices. Library of Natural Sounds, Cornell Laboratory of Ornithology and U.S.D.A. Forest Service.**

Booklet and tape cassette or CD. The best recordings of *R. a. draytonii* calls generally available.

**12. Davidson, C. 2004. Declining downwind: Amphibian population declines in California and historical pesticide use. Ecological Applications 14:1892-1902.**

Using the same *R. draytonii* data set as Davidson et al. (2002), the author concluded that total upwind pesticide use, especially organophosphates and carbamates, was a strong correlate of population disappearances.

**13. Davidson, C., H.B. Shaffer, and M.R. Jennings. 2001. Declines of the California red-legged frog: Climate, UV-B, habitat, and pesticides hypotheses. Ecological Applications 11:464-79.**

Testing four hypotheses (climate change, UV-B radiation, pesticides, habitat destruction) for their relevance to the disappearance of red-legged frogs from habitats in California, the authors determined that frogs had disappeared disproportionately from lower latitudes, from higher elevations, from near urbanized centers, and upwind of agricultural land use.

**14. Davidson, C., H.B. Shaffer, and M.R. Jennings. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B, and climate-change hypotheses for California amphibian declines. Conservation Biology 16:1588-1601.**

Using a slightly different data set and more refined analytical techniques, the results for the red-legged frog are the same as those in Davidson et al. (2001).

**15. Doubledee, R.A., E.B. Muller, and R.M. Nisbet. 2003. Bullfrogs, disturbance regimes, and the persistence of California red-legged frogs. Journal of Wildlife Management 67:424-438.**

A model simulation concluded that winter floods and draining stockponds every two years benefited red-legged frog survival, whereas shooting adult bullfrogs was only effective with extreme effort. A strategy combining pond drainage with bullfrog shooting was the most effective at facilitating red-legged frog survival.

**16. Fellers, G.M. and K.L. Freel. 1995. A standardized protocol for surveying aquatic amphibians. Technical Report NPS/WRUC/NRTR-95-001. National Biological Service, Cooperative Park Studies Unit, University of California, Davis, CA. v+123 Pp.**

**17. Fellers, G.M. and P.M. Kleeman. 2006. Diurnal versus nocturnal surveys for California red-legged frogs. Journal of Wildlife Management 70:1805-1808.**

Many more frogs were detected during nocturnal surveys. However, diurnal surveys provided information on habitat structure, eggs, and tadpoles that was difficult to secure at night.

**18. Fellers, G.M., A.E. Launer, G. Rathbun, S. Bobzien, J. Alvarez, D. Sterner, R.B. Seymour, and M. Westphal. 2001. Overwintering tadpoles in the California red-legged frog (*Rana aurora draytonii*). Herpetological Review 32:156-157.**

Documentation of the relatively rare occurrence of overwintering tadpoles at several sites from Point Reyes south through the Bay Area to San Luis Obispo County, California.

**19. Fellers, G.M. and P.M. Kleeman. 2007. California red-legged frog (*Rana draytonii*) movement and habitat use: Implications for conservation. Journal of Herpetology 41:276-286.**

Many frogs were radiotracked on Point Reyes, Marin County, California. 66% of females and 25% of males moved from the breeding pond to non-breeding areas. Ponds were breeding habitat and streamsides were summer habitat.

**20. Gosner, N. 1960. A simplified table for staging anuran embryos and larvae with notes on identification. Herpetologica 16:183-190.**

The standard method for expressing the stages of amphibian embryos and tadpoles.

**21. Hayes, M.P. 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.**

Bullfrogs, habitat alteration, and introduced fishes have contributed to the decline of ranid frogs, with the latter probably having the most serious effect.

**22. Hayes, M.P. and M.R. Jennings. 1989. 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 in R.E. Szaro, K.E. Severson, and D.R. Patton (technical coordinators). Proceedings of the Symposium on the Management of Amphibians, Reptiles, and Small Mammals in North America. U.S. Department of Agriculture, Forest Service General Technical Report RM-166.**

*Rana aurora draytonii* recorded most commonly from intermittent streams that had pools >0.6 m deep and intact shoreline or emergent vegetation. Negative habitat components included bullfrogs, introduced fishes, and perennial water.

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

Differences between the subspecies suggest differentiation at the specific level, but critical specimens from the contact zone need to be analyzed.

**24. Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L-A.C. Hayek, and M.S. Foster (eds.). 1994. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington D.C. 364 pp.**

The bible for working with amphibians and their populations.

**25. Jennings, M.R. 1988b. Natural history and decline of native ranids in California. Pages 61-72 in H.F. DeLisle, P.R. Brown, B. Kaufman, and B.M. McGurty (editors). Proceedings of the conference on California herpetology. Southwestern Herpetologists Society Special Publication No. 4.**

Summary of biology and habitat for *R. draytonii*, and discussion of current threats.

**26. Jennings, M.R. and M.M. Fuller. 2004. Origin and distribution of leopard frogs, *Rana pipiens* complex, in California. California Fish and Game 90(3):119-139.**

Keys to California *Rana* adults and tadpoles, including *R. draytonii*.

**27. Jennings, M.R. and M.P. Hayes. 1995. Amphibian and reptiles species of special concern in California. Final report submitted to the California Department of Fish and Game, Inland Fisheries Division, Contract No. 8023. 255 pages.**

Distribution map for *R. a. draytonii* and summaries of its taxonomy, biology, and presumed threats.

**28. Knapp, R.A. and J.A.T. Morgan. 2006. Tadpole mouthpart depigmentation as an accurate indicator of chytridiomycosis, an emerging disease of amphibians. Copeia 2006:188-197.**

Lack of pigment in the mouthparts of tadpoles was a very accurate symptom of chytrid infection in *Rana muscosa* populations in the Sierra Nevada.

**29. Lawler, S.P., D. Dritz, T. Strange, and M. Holyoak. 1999. Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. Conservation Biology 13:613-622.**

In experimental ponds, *Gambusia* did not affect red-legged frog tadpole survival, but they did inhibit growth and delayed metamorphosis. Bullfrog tadpoles reduced survivorship of red-legged tadpoles to about 5%.

**30. McCasland, C., J. Davis, and D. Krofta. 2001. Endangered and threatened wildlife and plants: Final determination of critical habitat for the California red-legged frog; final rule. Federal Register 66:14626-14758.**

An accurate, up-to-date summary of the biology and habitat requirements of the California red-legged frog. Includes detailed maps and description of the 1,674,582 ha critical habitat.

**31. Miller, K.J., A. Willy, S. Larsen, and S. Morey. 1996. Endangered and threatened wildlife and plants: Determination of threatened status for the California red-legged frog. Federal Register 61:25813-25833.**

Notification of the listing the California red-legged frog as threatened under the Endangered Species Act.

**32. Moyle, P.B. 1973. Effects of introduced bullfrogs, *Rana catesbeiana*, on the native frogs of the San Joaquin Valley, California. Copeia 1973:18-22.**

The bullfrog appears to have displaced the red-legged frog from all of its former habitat in the San Joaquin Valley.

**33. Padgett-Flohr, G.E. and M.E. Goble. 2007. . Evaluation of tadpole mouthpart depigmentation as a diagnostic test for infection by *Batrachochytrium dendrobatidis* for four California anurans. Journal of Wildlife Diseases 43:690-699.**

Study of mouthparts of tadpoles of California *Bufo boreas, Bufo canorus, Pseudacris regilla*, and *Rana catesbeiana* concluded that mouthpart defects were not a good indicator of chytrid fungus infection.

**34. Rathbun, G.B. and J. Schneider. 2001. Translocation of California red-legged frogs (*Rana aurora draytonii*). Wildlife Society Bulletin 29:1300-1303.**

Describes juvenile and adult frogs homing after being moved from breeding pond. One adult male returned 2.8 km back to the breeding pond in less than 32 days.

**35. Rathbun, G.B., N.J. Scott, Jr., and T.G. Murphey. 1997. *Rana aurora draytonii* (California red-legged frog). Behavior. Herpetological Review 28:85-86.**

Red-legged frogs climbed over a fence designed to be a frog barrier.

**36. Reis, D.K. 1999. Habitat characteristics of California red-legged frogs (*Rana aurora draytonii*): Ecological differences between eggs, tadpoles, and adults in a coastal brackish and freshwater system. M.S. Thesis, San Jose State University, California. 58 pages.**

A multivariate analysis of habitats showed eggs and larvae were found in relatively shallow, warm water, with a high abundance of pondweed (*Potamogeton*) an indicator of larval habitat. Adults were found in deeper water.

**37. Shaffer, H.B., G.M. Fellers, S.R. Voss, J.C. Oliver, and G.B. Pauly. 2004. Species boundaries, phylogeography and conservation genetics of the red-legged frog (*Rana aurora/draytonii*) complex. Molecular Ecology 13:2667-2677.**

A definitive survey of the mitochondrial DNA of the complex, determining that *R. aurora* and *R. cascadae* are monophyletic sister species, and that *R. draytonii* is more distantly related. The zone of overlap is about 5 km wide south of Elk, southern Mendocino County, California, where the species may occur together in the same pond. Data from the last population in California south of Los Angeles, now effectively extinct, indicate that reestablishment efforts there should draw from populations in Baja California, rather than geographically closer but genetically more distant populations in Los Angeles and Ventura counties.

**38. Sjögren, P. 1991. Extinction and isolation gradients in metapopulations: The case of the pool frog (*Rana lessonae*). Biological Journal of the Linnaean Society 42:135-147.**

Best study of a ranid frog metapopulation. Ponds greater than 4 km from another pond with a frog population uniformly lacked frogs.

**39. Snyder-Velto, D.K. 2008. Moving quickly saves a breeding season. Endangered Species Bulletin 33:32-33.**

After a flood, a rapid response by the Forest Service and the Fish and Wildlife Service created breeding habitat for a critically vulnerable population of red-legged frogs, the last ones in Los Angeles County.

**40. Stebbins, R.C. 2003. A field guide to western reptiles and amphibians. Third edition. Houghton Mifflin Company, Boston, Massachusetts. 539 pp.**

Identification guide, distribution map, and illustrations of eggs, larva, and adults of the composite species *R. aurora*, including *aurora* and *draytonii*.

**41. Symonds, K. 2008. Ranchers restore amphibian-friendly ponds. Endangered Species Bulletin 33:30-31.**

Short description of a program developed by the Alameda County Resource Conservation District, the National Resource Conservation Service, and the Fish and Wildlife Service to encourage Alameda County ranchers to repair stock ponds, thus creating habitat for red-legged frogs and tiger salamanders.

**42. Tatarian, P.J. 2008. Movement patterns of California red-legged frogs (*Rana draytonii*) in an inland California environment. Herpetological Conservation and Biology 3:155-169.**

Less than half of 49 radiotagged frogs moved away from their source pools over two seasons. Most movement occurred after the first rains and before the breeding season. Upland sites where frogs located were closer to pools and had more cover than random sites.

**43. U.S. Fish and Wildlife Service. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). U.S. Fish and Wildlife Service, Portland, Oregon. 173 pp.**

Appendix D: Guidelines for voluntary pond management for the benefit of the California red-legged frog.

Appendix E: Private landowner incentives for implementation of conservation measures.

Appendix G: General guidelines for reestablishment of California red-legged frog populations.

**44. U.S. Fish and Wildlife Service. 2005. Revised guidance on site assessments and field surveys for the California red-legged frog. Web site: http://www.fws.gov/sacramento/es/documents/crf_survey_guidance_aug2005.doc.**

Current protocol for site assessments and frog surveys.

**45. U.S. Fish and Wildlife Service. 2006. Endangered and threatened wildlife and plants; designation of critical habitat for the California red-legged frog, and special rule exemption associated with final listing for existing routine ranching activities; final rule. Federal Register 71:19244-19292.**

A revision of McCasland et al. (2001) that greatly reduced the critical habitat from 1.7 million ha to 182,225 ha by ignoring the frog's biology, and by eliminating areas covered by Habitat Conservation Plans and existing or draft management plans of other agencies. Areas where the frog has been extirpated were also excluded.

**46. U.S. Fish and Wildlife Service. 2008. Endangered and threatened wildlife and plants; revised critical habitat for the California red-legged frog (*Rana aurora draytonii*); proposed rule. Federal Register 73:53492-53680.**

A proposal to fix, by using biological data, most of the problems of U.S. Fish and Wildlife Service (2006) by increasing critical habitat from 182,225 ha to 730,402 ha. The comment period ended in November, 2008.

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19 February 2009
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**SCORING PONDS AND SMALL STREAMS AS BREEDING HABITAT FOR CALIFORNIA RED-LEGGED FROGS (*Rana draytonii*)**

This scoring system is based on our experience, the experience of others, and the literature. It is highly subjective and the scores indicate which factors we believe to be most important to red-legged frog breeding and which factors seem to be less important.

The system is probably not suitable for large rivers and lakes, complex aquatic systems, or those influenced by sea water (e.g., Russian River, Pescadero Marsh, San Simeon Creek lagoon). Intermediate scores can be applied subjectively. Maximum score is 52. Red-legged frogs probably will not consistently breed in habitats that score zero for one or more of the factors with an asterisk, or if the overall score is less than about 20.

**Sufficient duration (through July or August)***

- Pools with tadpole habitat present through August ....5 points
- Pools do not hold water through July in most years....0 points

**Exotic fishes, or fishes with cover for frog escape***

- No fish.....5 points
- Mosquitofish or crayfish.....3 points
- Exotic predatory fish with little or no tadpole cover (also possibly *Xenopus*).....0 points

**Distance to other breeding areas***

- Two or more breeding sites within 500 m.....5 points
- No other breeding sites within 2 km.....0 points

**Water flow***

- No flow (ponds or pools in creek).....5 points
- Yearly flushing flows.....0 points

**Pond Nutrients***

- High level of nutrient input (livestock, sewage).....5 points
- Low level of nutrient input (deep well, spring water..1 point

**Egg and tadpole rearing area**

- Greater than 0.1 ha.....5 points
- Less than 0.01 ha.....1 point

**Summer water temperature (warmer the better)**

- Above about $80^0$ F.....5 points
- Below about $60^0$ F.....0 points

**Bullfrogs**

- No bullfrogs.....3 points
- Bullfrogs abundant and reproducing.....0 points

**Metamorph habitat* (little is known about this variable)**

- Aquatic micro-habitat with good cover (e.g., cattails) and few or no adult red-legged frogs or bullfrogs.....3 points
- No cover and abundant adult frogs or other predators..0 points

**Aquatic vegetation**

- Mosaic of open and vegetated water.....5 points
- Choked with vegetation.....2 points
- No vegetation (a rocky cobble substrate can substitute for vegetation in a stream).....0 points

**Urban proximity**

- Urban development further than 1 km.....2 points
- Urban development closer than 200 m.....1 point

**Pond persistence**

- Dries up in fall at least every 2-4 years.....2 points
- Never dries up.....0 points

**Summer / juvenile refuges***

- Summer/juvenile refuges at site or within 200 m.....2 points
- Summer/juvenile refuges >2 km away.....0 points

25 February 2009
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# STOCKPOND MANAGEMENT FOR THE BENEFIT OF CALIFORNIA RED-LEGGED FROGS

## (*Rana draytonii*)

In many California red-legged frog populations, artificial ponds maintained for watering livestock provide habitats for all the life stages of the frogs. In some cases, these ponds are the principal sources of young frogs that annually repopulate the system. In dry areas, a pond can represent a long-lasting water source. At wetter sites, ponds are often the only quiet water sites for egg-laying and tadpole development outside of swiftly flowing streams. In both areas, ponds can give a stability and predictability that would not ordinarily be present.

However, in some special cases, ponds can be extremely detrimental to red-legged frogs. Perhaps the most common nuisance pond is one that attracts and provides habitat for exotic predators, including bullfrogs (*Lithobates catesbeiana*), crayfish (usually *Procambarus*), and predatory fish. In many instances, these predators eliminate red-legged frogs. Another type of detrimental pond is one that becomes an attractive nuisance by attracting breeding adults, but then it dries up before tadpoles can undergo metamorphosis. These types of ponds can eliminate the entire reproductive output of the frogs that breed in them, with possible serious consequences to a metapopulation of frogs over time.

California red-legged frogs have evolved in California's Mediterranean climate with wet winters and springs and long dry summers and falls, but most of their introduced predators have not. In most cases, pond management that mimics the natural water cycle will be most beneficial for red-legged frogs.

## Red-Legged Frog Biology

Ponds that successfully enhance California red-legged frog populations must complement their biology. The frogs breed from December to April in ponds and streams. They seem to choose the sites that have the warmest water available, as long as it is at least 20 cm deep, and will persist long enough for tadpole metamorphosis. Eggs hatch in a few days, depending on temperature, and the tadpoles develop through the spring. Usually, they start to transform into froglets in July, and by late August most have completed the process. Tadpoles usually do not overwinter, but it does occur.

Outside of the breeding season, adult frogs seek out deeper water (>1 m) for escape from predators. In some areas, late summer water can be very scarce, and in these circumstances frogs will travel up to several hundred meters to congregate in well boxes, deep water holes in drying streams, and around small springs and seeps. They can also take refuge in damp leaf litter or duff for short periods of time. With the first soaking rains of fall, frogs tend to move away

from their summer refuges. During a rainy winter, they may establish a temporary residence quite a distance from any body of water. At this time they often gradually move towards the late winter breeding site.

## Choosing a Site

Stock ponds can be useful for rehabilitation and enhancement of red-legged frog populations, but only if the frogs can get to them. The transport and re-establishment of red-legged frogs into areas where they do not now occur can do more harm than good and thus is under tight regulation by the Fish and Wildlife Service. It is only considered after intensive studies of the site, with guarantees that the donor population will not be damaged. Given this, ponds for the benefit of red-legged frogs are limited to areas that already contain at least a remnant population. In such areas, if the ponds are suitable, the frogs will find them on their own; they do not need to be moved.

Ponds should be located as far as possible from predator source-areas. Bullfrogs from a pond with a large population will quickly invade a new pond up to a few hundred meters away, but it should take them longer to build up to damaging population levels if the ponds are separated by a kilometer or more. Raccoons (*Procyon lotor*) are a serious red-legged frog predator in many places, especially where they build up to many times the normal population density in urban areas and campgrounds with a plentiful supply of garbage and pet food.

## Pond Design

Suggestions for pond design are based on observations of frogs in many habitats, but they have not been experimentally tested for efficacy. Further research will surely modify or eliminate some of these suggestions. The final design depends on a number of non-biological considerations such as the terrain, the use of the pond, and the adequacy and timing of the water supply. From a biological point of view, pond design is most tightly restricted when exotic predators are present in the area.

The ideal pond probably has two main components: A deep-water portion and a shallow tadpole- and juvenile-rearing section. The former should have holes that are deep enough (probably > 1.5 m) to discourage aquatic emergent plants, such as willows (*Salix*), cattails (*Typha*) and bulrushes (*Scirpus*), from growing and thus shading the entire pond. These deep portions also provide predator escape for adult frogs. Mats of floating and submerged aquatic vegetation in deep water seem to be ideal for adult frogs in the non-breeding season. Predators such as raccoons and herons (Ardeidae), and even large bullfrogs, probably find it difficult to reach red-legged frogs on floating mats.

The tadpole-rearing portion should be unshaded and shallow enough

to warm quickly in the winter sun. Submerged aquatic vegetation seems to be tolerated, but a dense cover of emergents such as willows, cattails, or bulrushes seems to discourage breeding because the water tends to be much cooler. The pond must contain water for tadpole development during the entire rearing season (minimally February through August in most areas), but it can be allowed to dry at other times of the year.

If the main pond dries regularly, adult frogs will use a summer refuge. In places with a high water table, these can be well boxes if they have deep, perennial water and protecting vegetation. Small springs can also be modified with a collection box or small dam to serve as summer refuges.

## Discouraging Predators

Perhaps the most important factor in discouraging aquatic vertebrate predators of red-legged frogs is to provide a way of drying perennial ponds with the installation of a drain. If the pond can be regularly and completely drained, even once every three or four years, bullfrog, crayfish, predaceous insect, and exotic fish populations will be greatly reduced or eliminated. Bullfrog eggs are laid in spring and early summer (April-July), and the majority of tadpoles do not transform until the following year. If the pond is completely drained in the fall or winter, bullfrog (and fish) life cycles will be interrupted.

Bullfrog tadpoles and adults are often associated with deep water, and extensive shallow, marshy areas may favor red-legged frogs. Also, small isolated ponds a few meters across, such as excavated springheads, may harbor red-legged frogs, but may not be attractive to bullfrogs.

Chemical means of bullfrog tadpole and fish control are possible, but their use requires the permission of the California Department of Fish and Game and the U.S. Fish and Wildlife Service to ensure that red-legged frogs and other native wildlife will not be harmed.

## The Role of Grazing

Pond management usually needs to be integrated with the local livestock grazing program. Grazing can be an important tool to help keep the shallower, tadpole-rearing portions of the pond free of emergent vegetation that shades the water. However, these shallows should not be churned into a mucky mire. This can be accomplished by varying the number of livestock using the site and by ensuring that the water is deep enough. Ponds with fluctuating levels where the shallow portions are flooded in the winter (breeding season), but dry each summer (after metamorphosis) appear to be ideal.

Many ponds used by cattle gradually become shallow mud holes, caused by cattle trampling the banks. To prevent this, portions of the pond should be fenced so that cattle cannot enter. This can be done in a manner such that the primary function of the pond to

provide livestock water is not compromised, but some deep escape water and some shallow breeding habitat is protected for frogs. In fencing out cattle, consideration should also be given to protecting nearby densely vegetated terrestrial habitats that frogs may use as short term refuges when a pond dries.

The critical period for livestock water on many California ranges is late summer and early fall. Draining of ponds for bullfrog and fish control needs to accommodate livestock needs. For example, a temporary catch basin below the drained pond could provide livestock water. Water in the catch basin could be maintained until the main pond refills, then drained. A catch basin should also be used if there is danger of releasing unwanted predators into a downstream body of water.

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15 March 2002
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