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DECLINES OF THE CALIFORNIA RED-LEGGED FROG: CLIMATE, UV-B, HABITAT, AND PESTICIDES HYPOTHESES

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Abstract. The federally threatened California red-legged frog (*Rana aurora draytonii*) has disappeared from much of its range for unknown reasons. We mapped 237 historic locations for the species and determined their current population status. Using a geographic information system (GIS), we determined latitude, elevation, and land use attributes for all sites and analyzed the spatial pattern of declines. We then compared the observed patterns of decline to those predicted by the climate change, UV-B radiation, pesticides, and habitat alteration hypotheses for amphibian decline. Declines were not consistent with the climate change hypothesis but showed a strong positive association with elevation, percentage upwind agricultural land use, and local urbanization. These results apply to patterns of decline across the entire range of *R. a. draytonii* in California, as well as within geographic subregions. The elevational gradient in declines is consistent with the UV-B hypothesis, although the UV-B hypothesis also predicts a north-to-south gradient in declines, which we did not observe. The association of declines with the amount of upwind agricultural land use strongly suggests that wind-borne agrochemicals may be an important factor in declines. This association was most pronounced within the Central Valley–Sierra region, where other studies have documented both transport and deposition of pesticides to the Sierra Nevada and the presence of pesticide residues in the bodies of congeneric (*Rana muscosa*) and more distantly related (*Hyla regilla*) frog species.

Key words: amphibian decline; California red-legged frog; climate change; declining amphibians; geographic information system (GIS); habitat alteration; pesticides; Rana aurora draytonii; *spatial analysis; upwind agricultural land use; UV-B; wind-borne agrochemicals.*

INTRODUCTION

Since they were first brought to the attention of the herpetological and conservation biology communities a decade ago (Barinaga 1990, Wake 1991), amphibian population declines have become a focal issue in both the scientific and popular media (for recent summaries, see Alford and Richards 1999, Corn 2000). Although controversy still persists over the existence, intensity, and optimal ways to document these declines (Shaffer et al. 1998, Alford and Richards 1999), most researchers now agree that many species and some entire communities (Fisher and Shaffer 1996) of amphibians are undergoing ecological collapse. To date, researchers have used observational studies, sometimes combined with historic records, to document declines (Fellers and Drost 1993, Ingram and MacDonald 1993, Drost and Fellers 1996, Fisher and Shaffer 1996, Lips 1998, 1999). At the same time, laboratory studies (Long et al. 1995, Berger et al. 1998), field experiments (Blaustein et al. 1994, Kiesecker and Blaustein 1995, Ovaska et al. 1997, Anzalone et al. 1998, Lawler et al. 1999), and field-based correlational studies (Hayes and Jennings 1988, Bradford 1989, Corn and Vertucci 1992) have been used to elucidate possible causes of declines.

In this study, we develop a two-pronged approach to testing hypotheses for declines. First, we use historic records and recent distributional data to document spatial patterns of decline (Bradford et al. 1993, Jennings and Hayes 1994*a*, Fisher and Shaffer 1996). We then generate predictions of the spatial pattern of declines for competing hypothesized causal mechanisms, and we statistically compare the observed and predicted patterns. The power of this strategy resides in its broad, species-wide approach that avoids reliance on one or a few study sites, as well as the ability to simultaneously evaluate multiple hypotheses for causes of declines. In addition, the analysis of spatial patterns is a powerful and relatively quick method to assess possible causes of decline. The approach takes advantage of the extensive distribution data that already exist in natural history museums and recent surveys (Reznick et al. 1994, Shaffer et al. 1998, Wake 1998), and combines this information with often readily accessible geographic information system (GIS) data on land use, elevation, and other factors.

Like many amphibians in western North America

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