Plains Leopard Frog (*Rana blairi*):
A Technical Conservation Assessment

**Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project**

December 20, 2005

Brian E. Smith, Ph.D.[1] and Douglas A. Keinath[2]
[1]Department of Biology, Black Hills State University, 1200 University Street, Unit 9044, Spearfish, SD 57799-9044
[2]Wyoming Natural Diversity Database, University of Wyoming, P.O. Box 3381, Laramie, WY 82071

Peer Review Administered by
Society for Conservation Biology

Smith, B.E. and D.A. Keinath (2005, December 20). Plains Leopard Frog (*Rana blairi*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/plainsleopardfrog.pdf [date of access].

ACKNOWLEDGMENTS

We would like to thank the USDA Forest Service for funding this project. Gary Patton of the USDA Forest Service and Jeff Parmalee from Simpson College, Indianola, Iowa, provided editorial comments. Charles Lamb, chair of the Science Department at Black Hills State University, allowed time to work on this report. Sharon Hemmingson, also of Black Hills State University, helped to administer the grant.

AUTHORS' BIOGRAPHIES

Dr. Brian Smith is an associate professor in biology at Black Hills State University. His areas of research expertise include herpetology, biostatistics, and landscape ecology. He has conducted herpetological research in the Philippines, Peru, Guam, Costa Rica, Guatemala, and the Caribbean. He has also worked on the herpetofauna of Louisiana, Texas, New Mexico, and Arizona, and he spent four years working in the Department of Herpetology at the Dallas Zoo. For the last 10 years he has been working on reptiles and amphibians in the Badlands and Black Hills of western South Dakota and in the Bear Lodge Mountains in northeastern Wyoming. Dr. Smith received his B.S. from Washington State University in 1980, his M.S. from Louisiana State University in 1983, and his Ph.D. from the University of Texas at Arlington in 1996.

Doug Keinath is the Senior Zoologist for the Wyoming Natural Diversity Database, a research unit of the University of Wyoming and a member of the Natural Heritage Network. He has been researching Wyoming's wildlife for the past nine years and has 11 years experience in conducting technical and policy analyses for resource management professionals. His broader scope of research focuses on bat and small mammal ecology, survey, and monitoring at the population and landscape scales, and more recently on the spatially explicit predictive distribution modeling of sensitive elements (i.e., animals, plants, communities) of the Rocky Mountain West. Mr. Keinath earned a B.S. in Interdisciplinary Engineering (1993; *magna cum laude*) and a B.S. in Natural Resource Management (1993; with Distinction) from the University of Michigan. In 2000 he earned a M.S. in Wildlife Biology from the University of Wyoming.

COVER PHOTO CREDIT

Adult plains leopard frog (*Rana blairi*). Photograph by Suzanne L. Collins, The Center for North American Herpetology. Used with permission.

Summary of Key Components for Conservation of the Plains Leopard Frog

The status of the plains leopard frog (*Rana blairi*) is currently unknown in Region 2. Almost no peer-reviewed data are available on its abundance or population trends, and contradictory information exists over its decline in some parts of its range. Non-peer-reviewed publications (mostly field guides) indicate that this species appears to be common throughout the center of its range in the Great Plains states, from northern Texas to Nebraska, but is uncommon around the periphery of its range. This is not unusual for most species. Local declines may be occurring in Colorado and Illinois. Arizona populations are probably in danger of extinction; no work appears to have been done in the state since 1989, and the species does not have legal protection there.

Lack of data precludes a comprehensive discussion of threats to this species, as well as management actions needed for its conservation. However, we believe that the following issues are likely important to plains leopard frog conservation in Region 2, as these are important to virtually all anurans: habitat destruction and degradation, the introduction of non-native predators (especially bullfrogs and predaceous fish for sport fishing), and the introduction and spread of infectious diseases such as chytridiomycosis and ranavirus, both of which can be spread by amphibians, introduced fish, and humans. Other threats and conservation considerations peculiar to the plains leopard frog may exist as well but have not yet been identified.

Table of Contents

EDITOR: Gary Patton, USDA Forest Service, Rocky Mountain Region

List of Figures

Figures:

Introduction

Goal

This conservation assessment of the plains leopard frog (*Rana blairi*) was prepared in support of the Species Conservation Project for Region 2 of the USDA Forest Service (USFS). The plains leopard frog was selected because it is listed as a sensitive species by Region 2. Within the USFS, a sensitive species is a plant or animal whose population viability is identified as a concern by the Regional Forester because of significant current or predicted downward trends in abundance and/or habitat capability that would reduce its distribution. The plains leopard frog was classified as sensitive due to recently observed declines in abundance and distribution across its range. (http://www.fs.fed.us/r2/projects/scp/evalrationale/rationales/amphibians/plainsleopardfrog.pdf). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology, ecology, conservation status, and management of the plains leopard frog throughout its range, with specific reference to the geographic and ecological characteristics of Region 2. Our goal is to provide a current summary of published information and an expert interpretation of this information that can be used to develop management strategies and plans.

Scope, Uncertainty and Limitations

While some of the literature on this species originates from within Region 2, this assessment also includes information from plains leopard frog studies conducted outside the region. This assessment attempts to place that literature in the ecological and social contexts of Region 2. Similarly, we focus on the characteristics of the plains leopard frog in the context of current environmental conditions with comparisons made between current and historical status.

In writing this assessment, we reviewed refereed literature, research reports, unpublished documents, Natural Heritage data, and consulted with expert scientists. Not all publications on plains leopard frogs were given equal weight in preparing this assessment. We emphasize information from peer-reviewed literature whenever possible because this is the accepted standard in science. However, unpublished data such as occurrence information from Natural Heritage Programs were used extensively to estimate distribution of this species. These data were standardized to the methods and level of accuracy used in the Wyoming Natural Diversity Database for occurrence data. In addition, selected web resources were referenced from agencies and organizations that publish current information online.

This assessment is based on the best scientific information currently available. While the authors did not conduct new research for this assessment, we provide synthesis and interpretation of the available information on the species in order to help expand understanding of the implications of that information. Synthesis of existing information was conducted to develop sensitivity/elasticity estimates.

In this assessment, the strength of evidence from research is noted and alternative explanations from modeling, critical assessments of observational data, and expert inference are described when appropriate. Where possible we tried to confirm expert opinion from several sources when there is little or no research to back up specific hypotheses.

Peer Review and Web Publication

Conservation assessments developed for the Species Conservation Project have been peer reviewed prior to publication on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of this assessment.

This species assessment will be published on the USFS Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/assessments/index.shtml) in order to facilitate its use by personnel of the USFS and other agencies, as well as the public. A link to this publication will also be available on the Wyoming Natural Diversity Database web site (http://uwadmnweb.uwyo.edu/wyndd/). Web publication makes this information on the plains leopard frog accessible more rapidly than publication as a report. It will also facilitate revision, which will be accomplished according to guidelines set by USFS Region 2.

Management Status and Natural History

Management Status

Federal designations

The plains leopard frog is not listed as threatened or endangered under the federal Endangered Species

Act. It is considered a sensitive species within Colorado by the USDI Bureau of Land Management (Bureau of Land Management - Colorado State Office 2000) and Region 2 of the USFS (U.S. Department of Agriculture 2003).

State designations

The plains leopard frog is a species of special concern in Colorado (Colorado Division of Wildlife 2003) and Indiana (Indiana Department of Natural Resources 2005), but it has no special status in the rest of its range (i.e., Arizona, Arkansas, Illinois, Iowa, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, South Dakota, Texas).

Although considered globally secure (G5) by NatureServe (NatureServe 2005), the plains leopard frog receives varying levels of concern at regional and local scales. It is considered secure (S5) within the Great Plains states in the heart of its range (i.e., Nebraska, Kansas, Oklahoma, Texas) as well as Iowa. It is apparently secure (S4) in Illinois and New Mexico and unranked in Missouri. At the edge of its range, it is considered vulnerable (S3) by Colorado and South Dakota and imperiled (S2) by Indiana and Arkansas. Isolated populations in Arizona are considered to be critically imperiled (S1).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are no published management plans or conservation strategies specific to the plains leopard frog. Although there are a few other mechanisms by which conservation could be implemented (see below), none are likely to be effective as a primary avenue for conserving this species across Region 2.

Many states have non-game regulations that prohibit unauthorized destruction of native, non-game wildlife. The enforcement of these regulations is often tied to state wildlife management plans, which generally contain lists of species thus afforded protection (e.g., Species of Special Concern, Sensitive Species, etc.). However, this protection generally takes the form of non-binding guidance on conservation needs or is limited to prohibitions of direct impact (e.g., poaching, poisoning) and does little to address the major threats to the species. Until state policies expand their scope of protection and concurrently demonstrate a fiscally feasible and legally defensible mode of enforcing this protection, they will remain marginally effective tools for conserving plains leopard frogs. Moreover, in Region 2 the plains leopard frog is only given formal sensitive status in Colorado, where it is listed by the Colorado Division of Wildlife as a species of State Special Concern, a designation that has no statutory significance under the state's endangered species program (Colorado Rev. Stat. Ann. §§33-2-109 et seq) and therefore has not resulted in coordinated conservation planning.

All 50 states are currently completing a Comprehensive Wildlife Conservation Strategy (CWCS), as required by the Consolidated Appropriations Act of 2005 (Public Law 108-447) for federal funding through the State Wildlife Grants Program. This program is intended to augment the ability of state wildlife management agencies to manage and conserve wildlife, especially non-game species, by providing federal funding for wildlife in need of conservation and their habitat. States are required to compile a list of Species in Greatest Need of Conservation and the comprehensive strategy must identify the means by which states will monitor and manage these species and their habitat. Of all Region 2 states, only Colorado includes plains leopard frog on its Species in Greatest Need of Conservation, while the bulk of its distribution in these states occurs in Kansas and Nebraska. This limitation combined with the fact that CWCS funds are dispersed among a large list of species, make it unlikely to have an immediate or substantial impact on plains leopard frogs in Region 2. However, since the CWCS program is in the early stages of implementation, this is only an educated guess.

The National Forest Management Act (16 U.S.C. 1600 et seq.) directs the USFS to manage National Forest System lands to preserve biodiversity. This implies that forest management units should develop and implement management strategies to preserve species and their habitats in national forests. However, prior to this assessment, there have been no plans or measures for the plains leopard frog written at the regional level in Region 2. Furthermore, no habitat protection measures specific to plains leopard frogs were included in forest plans within the Region. Species with sensitive status (as the plains leopard frog) must be addressed in the NEPA process for any project or planning activity requiring such compliance. Effects on sensitive species must be analyzed in biological evaluations and mitigating measures or project modifications identified. Moreover, because plains leopard frogs are not monitored at the forest level on any forests in Region 2, it may be difficult to accurately evaluate how individual projects may individually or cumulatively affect the condition of the species at the forest level. There are no instances of which the authors are aware where this has had a discernable positive impact on population trends for plains leopard frogs in Region 2, so these mechanisms appear inadequate to conserve populations in the Rocky Mountains.

Biology and Ecology

When reading the following sections, one should be aware that a confounding factor that makes it difficult to assess the distribution and abundance of plains leopard frogs and possibly trends in population size is the fact that they can produce relatively fit hybrids with various other leopard frog species (Parris 1999, Parris et al. 1999, Semlitsch et al. 1999, Parris 2000, Parris 2001a, 2001b, Parris et al. 2001). Some authors (Post 1972, Gillis 1975, Dunlap and Kruse 1976, Cousineau and Rogers 1991, Baness 1997, Phillips et al. 1999) have also pointed out that natural hybrids occur. The relative ease with which various leopard frogs hybridize doubtless explains much of the taxonomic confusion that has arisen over the group.

Description and systematics

The plains leopard frog is a ranid frog of moderate size (5.1 to 9.0 cm long), with brown or green background color, and two or three irregular rows of dark spots on the dorsum (**Figure 1**; Conant and Collins 1991). The species is difficult to distinguish from the northern leopard frog (*Rana pipiens*), but it can be distinguished by the presence of a light spot in the middle of the tympanum, a distinct light line along the upper jaw, and "dorsolateral ridges [that are] interrupted just anterior to the groin and inset medially" (See fig. 104, p. 342, Conant and Collins 1991).

Meachem et al. (1973) were the first to apply the name *Rana blairi* to this species; this frog had previously been considered to be *R. pipiens*. Although by the time Pace (1974) published her extensive monograph on leopard frogs a consensus had developed concerning the taxonomic position of *R. blairi*, taxonomic confusion had existed for years within the *R. pipiens* group. Her monograph clarified the relationships of the leopard frogs and provided a synonymy of the species, to further solidify the taxonomy of the group. Using biochemical techniques, Hillis et al. (1983) further resolved the phylogeny of the Alpha and Beta groups of the *R. pipiens* complex. *Rana blairi*, along with *R. pipiens*, *R. sphenocephala*, and *R. berlandieri*, falls within the Beta division. The Alpha division contains *R. palustris*, *R. capito*, and *R. areolata*. Hillis (1988) further reviewed the literature and provided range maps of all the North American leopard frogs referred to the *R. pipiens* complex, including *R. blairi*. Lynch (1978) discussed the distribution of *R. blairi* and *R. pipiens* and zones of sympatry of the two species in Nebraska. Dunlap and Kruse (1976) discussed the distribution of the "northern" (*R. pipiens*) and "western" (*R. blairi*) "morphotypes" (now known as two distinct species) in the northern and central Plains states. From the discussion of Dunlap and Kruse (1976) it is clear that a zone of hybridization between *R. pipiens* and *R. blairi* may exist in south-central South Dakota and northeastern Nebraska. It is possible that frogs from central South Dakota and central Nebraska (Fort Pierre National Grasslands, Samuel R. McKelvie National Forest, and the eastern portion of the Nebraska National Forest) could be hybrids of the two species. All other leopard frogs studied by Dunlap and Kruse (1976) from Region 2 are clearly assigned to *R. pipiens* or *R. blairi*. However, and most importantly for management of *R. blairi*, most authors prior to 1974 confused the two species or were unclear about the species to which they referred. Even following 1974, various names or descriptions (such as the "western morphotype" of Dunlap and Kruse 1976) have been applied to *R. blairi*. This makes it very difficult to discuss the management and life history of *R. blairi* without equivocation and can be confusing to managers not familiar with the taxonomic uncertainty that reigned within the leopard frog complex for so long.

Distribution and abundance

Figure 2 shows the extent of the current and historical ranges of the plains leopard frog, as reported by Hillis (1988), Conant and Collins (1991), and Stebbins (2003). As its name implies, the plains leopard frog's range centers on the plains of southeastern Nebraska, Kansas, northern Missouri, and Illinois (See fig. 9, p. 26, Pace 1974). The eastern plains of Colorado and the western plains of Nebraska and Kansas are at the limits of this species' range (Pace 1974), as is northern Texas. In Region 2, the plains leopard frog is only likely to occur in eastern and southern Nebraska, Kansas, and southeastern Colorado (**Figure 3**).

On the whole, few data are available on the abundance of the plains leopard frog anywhere in its range, and most of the information we have comes from basic field guides, not from peer-reviewed sources or survey and inventory work. Occurrence data also come from historical as well as recent sources, precluding development of an accurate current picture of plains leopard frog abundance in most states.

Figure 1. Photographs of adult plains leopard frogs showing color variation. Used with permission of Suzanne L. Collins, The Center for North American Herpetology.

Figure 2. Approximate range of the plains leopard frog in North America, synthesized from Hillis (1988), Conant and Collins (1991), and Stebbins (2003). Dark green represents estimated contiguous range. Light green areas are extensions that encompass historic and some current, but disjunct, populations.

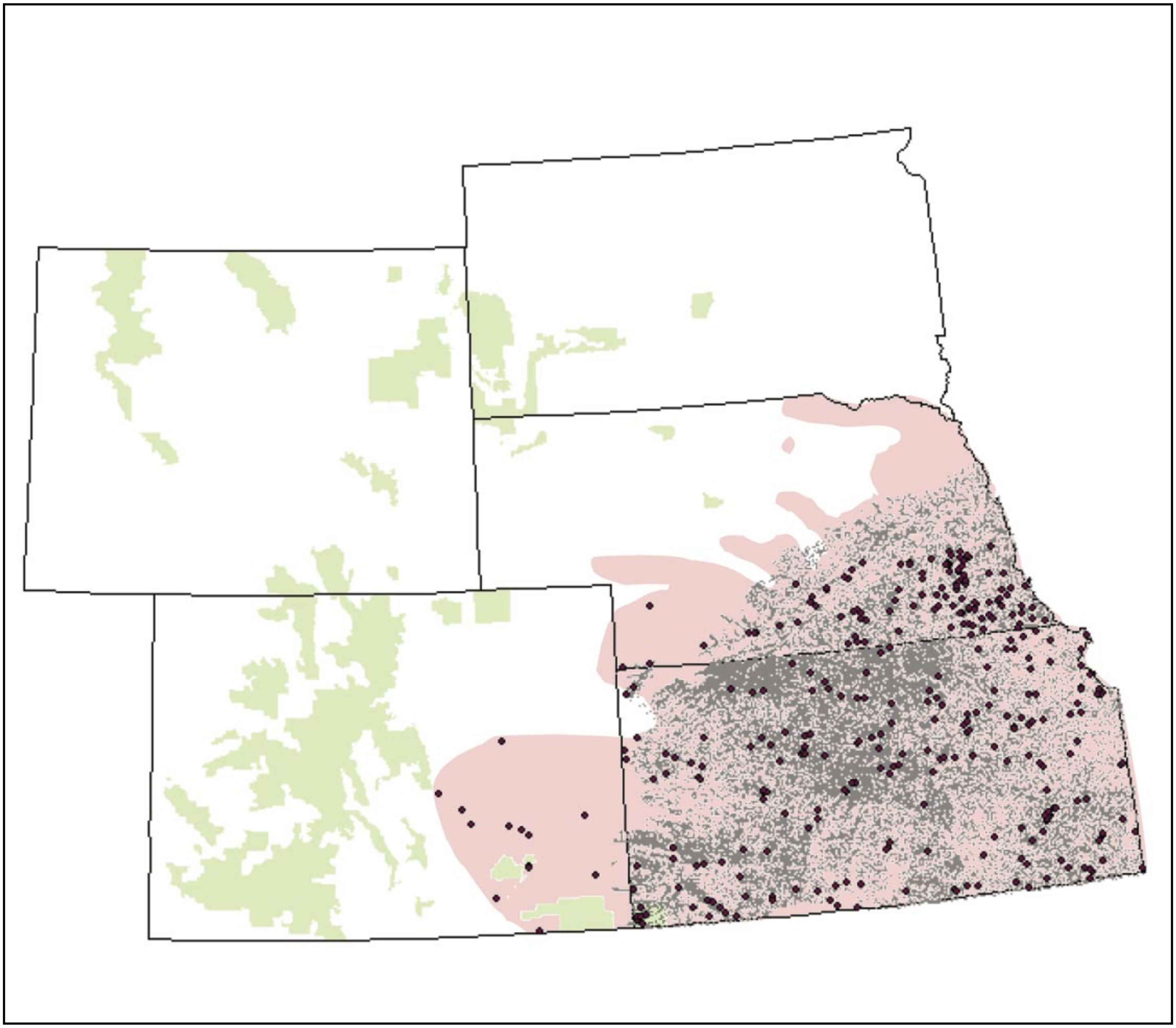

Figure 3. Probable range and distribution of plains leopard frog in USDA Forest Service Region 2 states. Green areas represent Region 2 administrative units, gray areas represent predicted suitable habitat for plains leopard frogs based on the maroon dots representing known occurrences of the species collected from Natural Heritage programs in each state shown on the map (see **Appendix A** and Beauvais et al. 2003, Beuvais and Smith 2005). Pink areas represent estimated range boundaries based on these occurrences and additional information from Lemen et al (2003) and Hammerson (1999). Image created at the Wyoming Natural Diversity Database for Region 2 and used with permission.

Although it remains widely distributed within southeastern Colorado, lack of adequate data makes it difficult to assess trends in abundance in the state (Hammerson 1999). It has become rare or absent where bullfrogs have been introduced in Colorado (Hammerson 1982). In Nebraska, Lynch (1985) depicted collection localities for the species but did not discuss the abundance of the frog. Collins (1993) stated that the plains leopard frog was common throughout Kansas.

Degenhardt et al. (1996) did not comment on the abundance of the plains leopard frog in New Mexico, but Scott and Jennings (1985) commonly found tadpoles in muddy tanks and rivers in the state. Bragg (1950a) reported that the plains leopard frog was widespread in Oklahoma at that time but did not report on its abundance. A database kept by the Oklahoma Biological Survey (http://www.biosurvey.ou.edu/dokadesc.html) lists 145 sightings in the state since the 1970's. Dixon (2000) stated that it was common in Texas.

Johnson (1987) reported that plains leopard frogs were widespread in Missouri, except in the Ozark Mountains, but gave no data on abundance. Due to similarities in calls, all leopard frog species in Iowa were censused as one "species" by Hemesath (1998), and while detailed data are not available, Christiansen (2001) thought that the range of the plains leopard frog might be expanding in that state. Phillips et al. (1999) reported that this species was widespread but not abundant in Illinois. In a summation of 45 years of collecting in Indiana, Minton (1998) did not mention the plains leopard frog.

We would also like to note that various sources draw contradictory conclusions about this frog. For example, it was declining in Texas (Platz 1981), but also common in Texas (Dixon 2000). In Iowa, Christiansen and Bailey (1991) noted declines and then a decade later declared that the frog was expanding its range (Christiansen 2001). Confusion about its abundance and population trends (next section) probably arises because there have been few published surveys or inventories within the range.

Population trends

Very little appears to be known about population trends in the plains leopard frog. We can only speculate that numbers may be declining to an unknown degree based on a few, scattered, ad hoc reports. Clarkson and Rorabaugh (1989) noted some declines in Arizona and mentioned acid rain as a possible cause. Phillips et al. (1999) also noted declines in Illinois, apparently the result of habitat destruction. Brodman et al. (2002) did not find plains leopard frogs at state-owned wildlife areas in Indiana where the species had been found in the 1930's. They gave no reasons for apparent extirpation of the species, although a variety of wetlands had been bulldozed and drained since the 1930's.

In Region 2, Hammerson (1999) noted local declines in the species in Colorado, possibly due to introduced bullfrogs (*Rana catesbeiana*) or polluted habitat. Personal communications with the author show that these declines refer specifically to populations on the Comanche National Grassland in southeastern Colorado, where the frog fauna along Carrizo Creek in Baca County shifted from clearly leopard frog dominated to overwhelmingly bullfrog dominated; while at Picture Canyon bullfrogs seem to have dominated for decades with few plains leopard frogs in the area. This is based on qualitative estimates and limited sampling. More work is needed to determine whether observed changes reflect a consistent trend (i.e., declining leopard frog populations) or variations associated with environmental changes that could eventually lead to reestablishment of leopard frogs as the dominant ranid (Hammerson personal communication 2005). Ehrlich (1979) reported that bullfrogs readily consumed plains leopard frogs. McLeod (2005) revisited Lynch's (1985) localities in Nebraska and found that plains leopard frogs had declined at these sites.

Activity and movement patterns

Unlike the northern leopard frog (Smith and Keinath 2005), there are no major studies of the movement patterns or activity of the plains leopard frog. In Colorado, they are active from March or April through September (Hammerson 1999). In late September and October, they tend to gather at large bodies of water in which they overwinter; but they may be active during warm periods through November (Hammerson 1999). Collins (1993) also noted that they overwintered in large bodies of water in Kansas. In Colorado, they may breed from April (Post 1972) to August (Gillis 1975). They have been known to move long distances, up to at least 8 km for the plains leopard frog and 14 km for a *Rana blairi* X *pipiens* hybrid (Gillis 1975). They are also a more arid-adapted species than the northern leopard frog (Gillis 1979) and tend to flee towards land when disturbed (Degenhardt et al. 1996, Hammerson 1999).

Habitat

Again, very little is known about the habitat preferences of plains leopard frogs. They hibernate in larger bodies of water (Collins 1993, Hammerson 1999) or on stream bottoms (Collins 1993) and presumably breed in smaller ponds (**Figure 4**), but their habitat requirements have not been carefully characterized. Collins (1993) stated that they might be found in all types of water bodies and frequently wander far from water. After breeding, they probably forage in areas around the breeding ponds, similar to northern leopard frogs (Smith and Keinath 2005), but since their habitat and movements have not been characterized, this is an assumption based on knowledge of other congenerics. Given their predilection for movement far from water (Gillis 1975, Collins 1993), this assumption may be incorrect, and they may range farther from water than other ranids. From Gillis (1979), it can be presumed that they tolerate drier conditions than northern leopard frogs, but how this affects their habitat requirements is unknown. They generally do not occur above 1,500 m elevation in Colorado, and the highest elevation at which they have been found is 2,130 m (Stebbins 2003).

Food habits

The food habits of the plains leopard frog were studied in some detail by Hartman (1906), who found beetles, grasshoppers, crickets, earthworms, and water snails in their stomachs. Befitting the more terrestrial habits of plains leopard frogs, Collins (1993) noted that they tended to eat non-aquatic invertebrates. Hammerson (1999) reported that they ate invertebrates and possibly small vertebrates on occasion. One frog in Colorado had eaten grasshoppers (Hammerson 1999).

Breeding biology

It is possible that many aspects of the breeding biology of plains leopard frogs may be similar to that of their congener, the northern leopard frog (Smith and Keinath 2005), but reproduction in the plains leopard frog has not been studied and some aspects are clearly different, especially the yearly timing of reproduction. According to Hammerson (1999), breeding may occur in temporary, semi-permanent, and permanent ponds, and also stream pools and backwaters lacking current. Bragg (1950a) noted that the species may favor temporary water sources in which to breed.

Figure 4. Photograph of occupied plains leopard frog habitat. Stock ponds are not typical habitat, but this demonstrates the range of conditions in which these amphibians can occur. Used with permission of Suzanne L. Collins, The Center for North American Herpetology.

In a comparison of the northern and plains leopard frogs, Pace (1974) pointed out that the plains leopard frog appears to be a facultative early metamorphosing species that frequently chooses more temporary habitats in which to breed and which has an unpredictable breeding period that may be tied to warmer rains. In contrast, the northern leopard frog breeds early in the season, with a pronounced breeding season shortly after snowmelt (Smith and Keinath 2005). In this sense, the plains leopard frog is more like an explosively breeding amphibian that breeds opportunistically later in the season. However, it is doubtful that its reproductive activity is very similar to classic explosively breeding anurans like the spadefoot toads (*Spea* spp.).

The breeding season of the plains leopard frog varies extensively from site to site, and has been recorded in April, May, June, and July (Post 1972), and in August (Gillis 1975) in Colorado. Collins (1993) reported that they breed from February into the summer in Kansas, and they may also breed in the fall (Caldwell and Glass 1976). Bragg (1950b) found that they breed from February to September in Oklahoma, and Bragg and Dowell (1954) found a clutch in October. Minton (1972) said that the species breeds in the spring in Indiana but frequently breeds later in the season. Johnson (1987) reported that they breed from mid-April to early June in Missouri. Post and Pettus (1967) and Post (1972) described the mating season as slightly earlier in the northern leopard frog and slightly later in the plains leopard frog, which kept the two species from hybridizing at their study sites. However, Hammerson (1999) found hybrids of these two species at the same sites.

Like the northern leopard frog (Smith and Keinath 2005), the plains leopard frog lays its eggs in masses on vegetation just under the surface of the water in shallow water (10 to 20 cm deep; Hammerson 1999). Hammerson (1999) reported between 200 and 600 eggs in each egg mass in Colorado, but Smith (1956) found clutches of 4000 to 6500 eggs in Kansas, Lynch (1985) reported clutches of 4000 to 6000 in Nebraska, Collins (1993) stated that egg masses in Kansas contained up to 6500 eggs, and Johnson (1987) reported that females laid from 4000 to 6500 eggs in Missouri. Bragg (1944) reported egg masses of less than 200 eggs on occasion (<10 percent of 200 masses examined). Amplectant pairs have been found in 11 °C water (Livo, cited in Hammerson 1999).

Eggs may hatch in five to 20 days (Smith 1956), considerably faster than reported by Smith and Keinath (2005) for the northern leopard frog. Johnson (1987) and Collins (1993) reported that eggs hatched in about three weeks. The tadpoles transform in about three months (Smith 1956), but they may also overwinter as tadpoles to transform the next spring (Bragg and Dowell 1954, Gillis 1975, Johnson 1987). In colder areas of their range, eggs laid later in the summer (such as those laid in August in Colorado) are likely to lead to overwintering as tadpoles (Gillis 1975).

The call of the plains leopard frog was described as “obviously different” from the northern leopard frog by Post (1972), but Hemesath (1998) thought that it was not possible for amateurs to distinguish the plains leopard frog from the northern leopard frog. Post (1972) described the call as “a long series of clucks followed by two or three low bursts of a grating sound”. He also provided sonograms of the call. The plains leopard frog also gives a loud distress call in response to predation attempts (Hammerson 1999).

Population demography

There are no data on population demographics anywhere within the range of the plains leopard frog. In the absence of further data, they may be assumed generally similar to those of the northern leopard frog summarized by Smith and Keinath (2005).

Community ecology

One way to concisely display ecosystem interactions is to construct an envirogram. Andrewartha and Birch (1984) describe envirograms, their construction, and their use as part of a “Theory of Environment” that seeks to organize the ecology of a species into a coherent and logically connected web of factors that influence its ability to survive and reproduce. An envirogram is essentially a dendrogram, the main stem of which is comprised of a “centrum” of components that act directly on the species under consideration. From this centrum are branches that “trace pathways from distal causes in the web toproximate causes in the centrum.” Three basic types of elements act upon the centrum: 1) resources, 2) malentities, and 3) predators; malentities differ from predators in that malentities represent hazards for which their reaction is zero, unlike the predator, which has a positive reaction. We have constructed an envirogram for the plains leopard frog (**Figure 5**), which represents a basic framework for the possible web of ecological relationships linked to the frog. This is not a comprehensive examination of the many potential relationships that exist, but instead it is a template that should be modified to represent

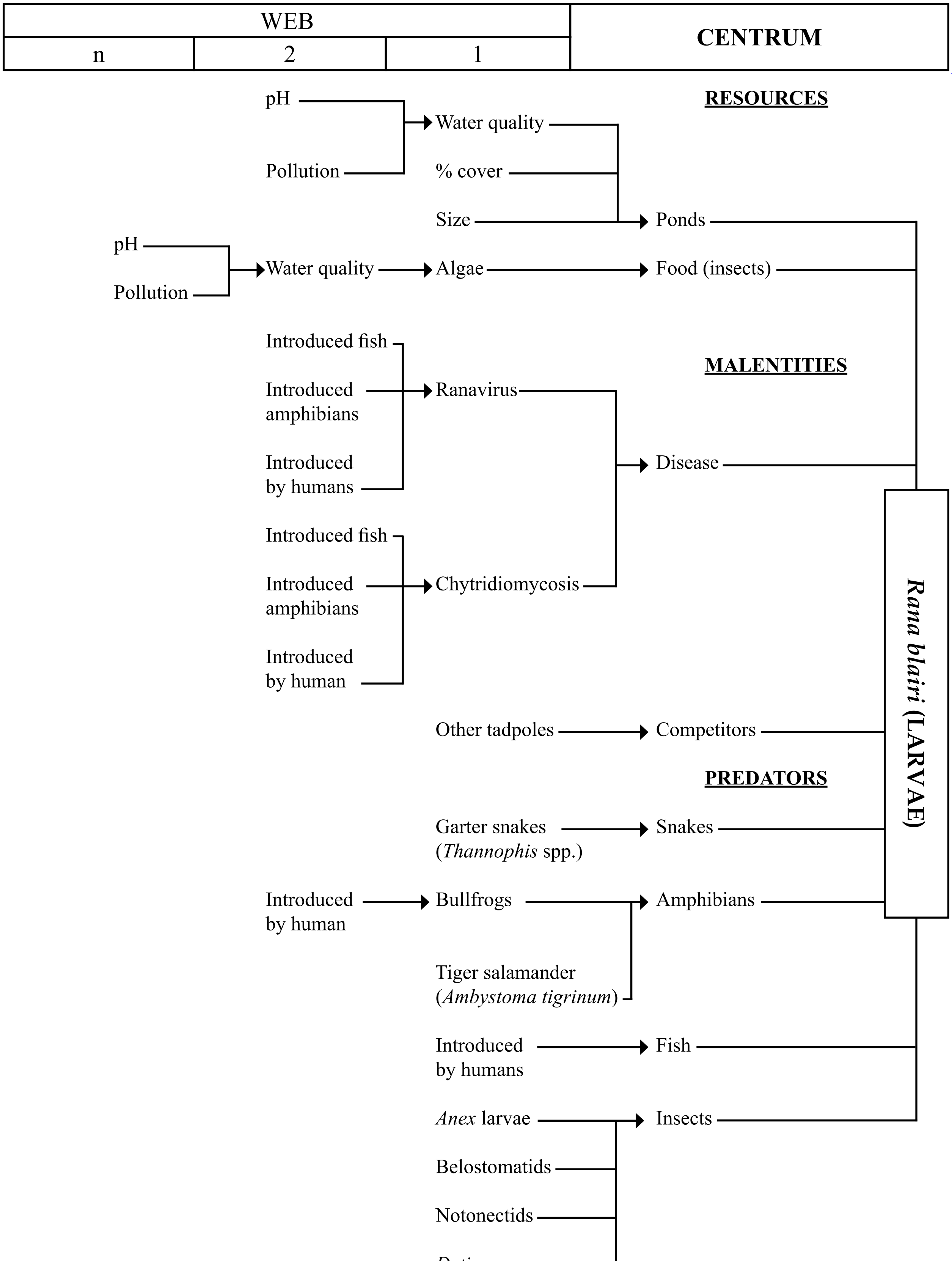

Figure 5a. Envirogram of tadpoles of the plains leopard frog.

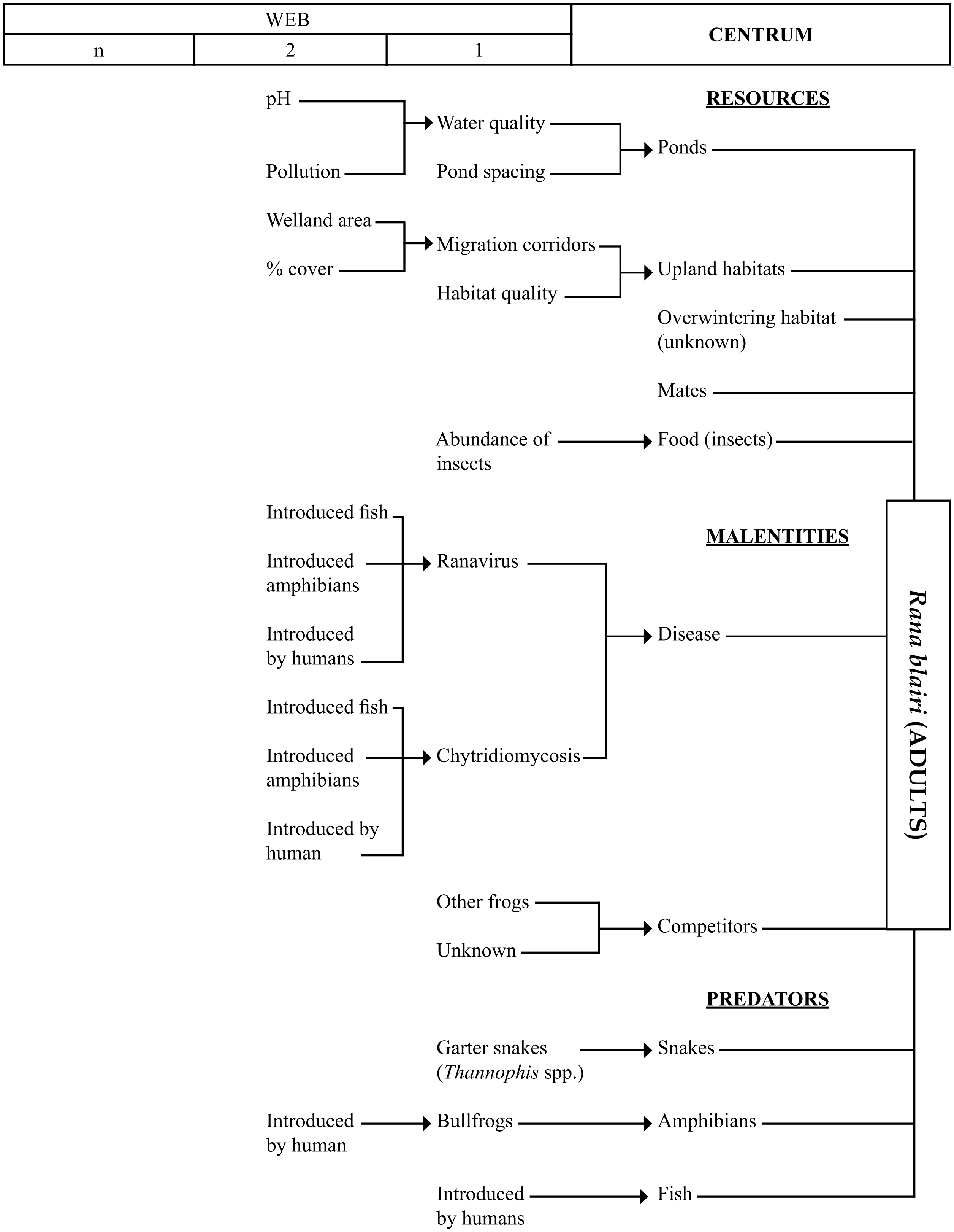

Figure 5b. Envirogram of post-metamorphic plains leopard frogs.

plains leopard frog populations across Region 2 in a variety of situations. Essentially, it should be viewed as a quick reference, highlighting some key linkages in the ecology of the frog, but by no means does it define this environment.

Three studies have been done on the ecology of the plains leopard frog (Parris 1998, Parris and Semlitsch 1998, Durnin and Smith 2001). Although the plains leopard frog has been characterized as a more arid-adapted frog relative to the northern leopard frog, Parris (1998) found that the plains leopard frog was less arid-adapted than other congeners such as *Rana areolata* and *R. sphenocephala*, neither of which occurs in Region 2. The plains leopard frog experienced considerable water loss in experiments designed to explore the burrowing performance of these three species, suggesting that it was the more mesic-adapted of the species tested. In another study, Parris and Semlitsch (1998) tested competition effects among the same three species, mostly to investigate the conservation of *R. areolata*.

In a study with management implications for Region 2, Durnin and Smith (2001) tested the effect of changing water volume on tadpoles of the chorus frog (*Pseudacris triseriata*) and the plains leopard frog. These species co-occur where the plains leopard frog occurs in Region 2 and may co-occur in temporary ponds, given what some authors have reported about the tendency for plains leopard frogs to occasionally breed in temporary water (Bragg 1950a, Hammerson 1999). Durnin and Smith (2001) found that chorus frogs were able to alter their time to metamorphosis as pond hydroperiod was artificially shortened. However, plains leopard frogs did not shorten their development time. Drying times in the experiment were not sufficient to cause mortality to plains leopard frogs, but Durnin and Smith (2001) suggested that the inability of plains leopard frogs to respond to quick drying times in natural ponds might account for occasional mass mortality of this species in temporary ponds.

Predators

Natural predators of the plains leopard frog include raccoons (*Procyon lotor*), opossums (*Didelphis marsupialis*), and skunks (Shirer and Fitch 1970) and garter snakes of various species (Hammerson 1999). Tyler (1991) reported predation on a plains leopard frog by a loggerhead shrike (*Lanius ludovicianus*). Introduced predaceous fish and introduced bullfrogs are well known predators of frogs of the genus *Rana* (Smith and Keinath 2005), and it is likely that they cause serious problems for plains leopard frogs as well. However, this problem is poorly studied in plains leopard frogs. Kruse and Francis (1977) reported predation by introduced centrarchids on plains leopard frogs. Ehrlich (1979) reported that bullfrog tadpoles ate larval plains leopard frogs as well as eggs of this species. While over-collection can be a problem for northern leopard frogs (Smith and Keinath 2005), plains leopard frogs are not typically collected for use as classroom dissection material or for other reasons (Smith personal observation).

Parasites and disease

Three basic types of diseases have been identified in amphibians: viruses, fungal infections, and bacterial infections (Carey et al. 1999). Of these three, Carey et al. (1999) and Daszak et al. (1999) wrote that only viruses and fungal infections have been implicated in mass mortality events. However, the bacterial diseases collectively called "red leg" have been reported to cause mass mortality events by Faeh et al. (1998). The term "red leg" may refer to the symptomology of a variety of different bacteria (Faeh et al. 1998) but is frequently associated with *Aeromonas hydrophila*, a bacterium blamed for the disappearance of boreal toads (*Bufo boreas*) at several sites in Colorado (Carey 1993). However, Carey et al. (1999) stated that they believed that bacterial infections were largely secondary to fungal and viral infections.

Specific types of iridoviruses known as ranaviruses are known to infect ranid frogs (Cunningham et al. 1996, Daszak et al. 1999), and some amphibian declines are blamed on this virus (Jancovich et al. 1997, Daszak et al. 1999). Daszak et al. (1999) reported that ranavirus was extremely lethal, with 100 percent mortality in tadpoles exposed to the virus. Tadpoles are most susceptible to the virus, but all life stages are vulnerable to the disease (Daszak et al. 1999). Infected metamorphs die without signs of infection, and infected adults show no overt signs or may display a general weakness (Daszak et al. 1999). Secondary bacterial infections are common in cases of ranavirus. Movements of amphibians like bullfrogs, which are commonly introduced, have probably moved ranaviruses around the country (Daszak et al. 1999). In addition, tiger salamanders (*Ambystoma tigrinum*) are often introduced around the country as fish bait, and this species has an iridovirus of its own (Daszak et al. 1999). The link between ranaviral infections and amphibian declines is less clear than the link between chytridiomycosis and amphibian declines (Daszak et al. 1999).

Chytridiomycosis, a disease of frogs caused by a chytrid fungus, has recently been blamed for frog declines around the world (Berger et al. 1998, Morell 1999, Daszak et al. 1999, 2000), and it has been found in other ranid frogs (Carey et al. 1999). The disease was first blamed for amphibian declines in Australia in 1998, but it probably emerged separately on two continents at around the same time (Berger et al. 1998) and has been found in frogs collected as far back as 1978 (Milius 2000). Of concern to persons involved with field surveys, chytrids may also frequently be spread by introduced amphibians or by boots or survey gear contaminated by the fungus. The signs of chytridiomycosis are loss of the righting reflex, lethargy, and abnormal posture (Daszak et al. 1999).

Carey et al. (1999) discussed hypotheses that could explain the apparent recent increases in the susceptibility of amphibians to infectious disease. Among several hypotheses they suggested is that these pathogens can be introduced to frog habitats by fish stocking, introduction of non-native amphibians such as bullfrogs or extralimital populations of tiger salamanders, wind-blown insects, the activity of birds or other animals, by workers monitoring amphibian ponds, or by anglers or other tourists. As a standard protocol for amphibian survey and monitoring, investigators should sterilize boots and other gear with a solution of 10 percent standard household bleach (1:10 by volume), leave this solution on gear for at least 10 seconds, and then rinse the gear with fresh water. This methodology is commonly used in veterinary clinics to prevent the transmission of virulent disease.

Plains leopard frogs are likely to be susceptible to the standard diseases of amphibians, especially ranavirus but also chytrid infections. However, no investigations have been conducted of disease specifically in the plains leopard frog. Like many amphibians, plains leopard frogs collected in the wild probably have a high parasite load. Baker (1985) described a new nematode from a "leopard frog" of Illinois, but was not sure from which of three leopard frog species it came.

Ultraviolet light

It has been hypothesized that more ultraviolet light penetrates the atmosphere because of the depletion of the protective ozone layer. Exposure to higher levels of ultraviolet light (UV-B) causes sublethal effects on plains leopard frog tadpoles (Smith et al. 2000), but Bruner et al. (2002) found that ambient levels of UV-B had no effect on developing plains leopard frogs. Smith et al. (2000) found that tadpoles raised from eggs exposed to nearly ambient levels of UV-B radiation grew and developed more slowly than those grown under sunlight filtered to 58 percent transmittance of ambient UV-B radiation. The authors suggested that, although higher levels of UV-B radiation do not kill embryos and tadpoles outright, these effects might well cause decreased fitness in later life stages.

CONSERVATION AND MANAGEMENT OF THE PLAINS LEOPARD FROG IN REGION 2

Conservation Concerns

Extrinsic threats

In Region 2, we think the plains leopard frog is threatened by the same factors that threaten many amphibians, namely habitat loss and fragmentation, introduced species, and water quality degradation. The factor most responsible for the loss and fragmentation of plains leopard frog habitat is likely conversion to cropland. Throughout much of the range of the plains leopard frog in Region 2, a large number of wetland sites have been drained and converted to cropland. In fact, the Great Plains of the United States may be one of the most altered habitats in the country due to extensive conversion to agriculture. The conversion of habitat to cropland has probably also extensively altered migration patterns since it no longer consists of a complex matrix, but rather monocultures of various crops. Throughout the range of the plains leopard frog in Region 2, there are few urban centers, and we doubt that urbanization has affected this species nearly as much as conversion to cropland. Because there are few abundance data for the plains leopard frog in Region 2, we cannot confirm or refute our assertion; however, the extensive loss of wetlands to agricultural uses is a strong surrogate indicator of probable decline. Because of the extensive habitat losses on private lands that predominate in the range of the plains leopard frog, we should note that although comparatively small, the Comanche and Cimarron national grasslands may be important island habitats that can serve as refuges for the species.

The effects of introduced species on amphibians are well documented, and a summary of this literature is well beyond the scope of this document. Introduced species that have detrimental effects on frogs are summarized in Smith and Keinath (2005). The plains leopard frog is probably similarly affected, especially by introduced predaceous fish, but also by bullfrogs on the western fringes of its range (Crawford et al.

2005). Hammerson (1999) has discussed extirpation of plains leopard frogs by introduced bullfrogs in Colorado although the ranges of bullfrogs and plains leopard frogs are largely coincident in Region 2. Introduced fish probably affect the species throughout its range in Region 2. The lead author has spent some time examining ponds on the plains of South Dakota, Wyoming, and Nebraska, and he has found that virtually all ponds have a suite of introduced predaceous fish that are no doubt affecting plains leopard frogs where they now occur or occurred historically. However, we have no data to quantify the effects of these fish on plains leopard frogs, and once again we are unable to do more than speculate in the absence of data.

Water quality has probably been seriously compromised within Region 2 due to extensive use of pesticides and fertilizers by the agricultural industry. Most tests of toxicity of the various agents used on cropland have been conducted on the northern leopard frog. We would refer the interested reader to Smith and Keinath (2005) for a discussion of the effects of pesticides and fertilizers on the northern leopard frog. Presumably, these agents act similarly on the congeneric plains leopard frog. National Forest System lands could be particularly important habitats for the plains leopard frog since these lands are not subjected to heavy pesticide use.

However, cattle grazing, which does occur on National Forest System lands, also has the capability to seriously degrade water quality (Buckhouse and Gifford 1976, Van Velson 1979, Kauffman and Krueger 1984, Elmore and Beschta 1987, Jefferies and Klopatek 1987) and is known to have detrimental effects on all life stages of frogs (Ross et al. 1999, Reaser 2000). Cattle can affect breeding ponds indirectly through erosion and degradation of pond margins and riparian zones. Like fish eggs, frog eggs respire through their surface, and anything that covers the surface (e.g., silt) impedes oxygen flow. Cattle can affect tadpoles in breeding ponds through the toxic effects of nitrogen buildup in ponds to which cattle have access. Post-mortem of two diseased northern leopard frog tadpoles collected at one pond accessible to cattle in 1998 showed that the tadpoles had deformed mouthparts and skin irritation consistent with exposure to an aquatic irritant (Smith unpublished data). Smith and Keinath (2005) discussed the effects of cattle grazing on northern leopard frogs at length, and we would suggest that these effects would be at least as severe for plains leopard frogs, if not more so, since the lowland habitats of plains leopard frogs are probably more heavily used for cattle grazing. This should be cause for concern on National Forest System lands where grazing is allowed and prevalent.

Abundance and distribution trends

Although considered to be less abundant than in the past by some authors (Hayes and Jennings 1986, Brown 1992, Hammerson 1999, Phillips et al. 1999), and listed under various categories of threat by agencies and state governments, there appears to be little to no evidence of this status in the literature. Hammerson (1999) pointed out that the plains leopard frog has declined or been extirpated in parts of Colorado where bullfrogs have been introduced, and Crawford et al. (2005) noted that it has presumably declined in areas under cultivation. McLeod (2005) found that it had declined across Nebraska. Various authors, summarized in Crawford et al. (2005), have found population extirpations within the range of the plains leopard frog, but the reasons for these extirpations are not known, except in Colorado, where bullfrogs have apparently eliminated populations in areas where they have been introduced (Hammerson 1982, Hayes and Jennings 1986, Cousineau and Rogers 1991, Brown 1992).

It is possible that plains leopard frogs are declining in Region 2, and we have cited several authors that have noted declines and extirpations. Still, Hammerson (1999) noted that they remain common in much of their historic range in Colorado, and there are few data from the rest of their range in Region 2. As we have noted elsewhere (Smith and Keinath 2005), data that do not show declines may not be published, leading to the erroneous conclusion that certain species are declining when this may not be the case. Fogell (personal communication with lead author 2005) suspects that plains leopard frogs are actually displacing northern leopard frogs within Nebraska. Because there are few data on this species, and some of it is conflicting data, it is not clear to us that the plains leopard frog is undergoing serious declines. We recommend that surveys be conducted and monitoring programs be emplaced for this species throughout its range in Region 2. We also direct the reader to the next section, "Intrinsic Vulnerability", for examples of factors that could cause declines in the plains leopard frog.

Intrinsic vulnerability

Like many frogs, the plains leopard frog may be intrinsically vulnerable for a number of reasons, each of which is discussed below:

- ❖ they use small ponds for reproduction

- ❖ they use upland habitats for summertime foraging
- ❖ they have permeable skin
- ❖ fatal diseases could be present to which the species may be vulnerable
- ❖ they are vulnerable to predation by introduced predaceous fish
- ❖ overland migration routes, which are needed to reach and colonize new ponds, are disrupted
- ❖ metapopulation dynamics are disrupted.

Breeding pond habitat has not been studied in the plains leopard frog, but it is probably similar to that used by its congener, the northern leopard frog (Smith and Keinath 2005). Ponds of the size often used for breeding by frogs are typically not protected by law (Semlitsch 2000a) and are not often discussed in management plans. It is imperative that management plans take into consideration the presence of small ponds across the landscape and protect these ponds to foster healthy populations of any species of frog.

Closely tied to the use of small ponds for reproduction is the species' use of upland habitats surrounding breeding ponds for summertime foraging. Working with various species of salamanders that reproduce in ponds in the spring, Semlitsch (1998) found that an upland area of up to 164 m surrounding each breeding pond might be sufficient to protect 95 percent of the adult population. We would imagine that this area might be larger for a more terrestrial ranid like the plains leopard frog, but such work has not been done on frogs. This is a critical information need.

The skin of freshwater amphibians is highly permeable (Duellman and Trueb 1986), so it is likely that many toxins could be incorporated into their bodies. Also, since it is likely that plains leopard frogs serve as prey for a variety of species, the presence of toxins in their bodies would have repercussions throughout the food web of a habitat in which they occurred. Like the northern leopard frog, the plains leopard frog might serve as a key indicator species in ecosystems in which it occurs. However, little work has been done on toxins in the plains leopard frog. This is probably a key information need and should possibly be monitored on National Forest System lands throughout the species' range in Region 2.

Chytridiomycosis and ranavirus have emerged as critical threats to northern leopard frogs in many parts of their range (Cunningham et al. 1996, Jancovich et al. 1997, Carey et al. 1999, Daszak et al. 1999), and they are likely to be so in plains leopard frogs as well. Currently, these diseases are not monitored, and there are many potential vectors that could introduce these diseases into breeding ponds used by plains leopard frogs. Predatory game fish are frequently introduced by various agencies into watersheds in which frogs breed, accidental or intentional introductions of predatory fish and fish bait (e.g., salamanders), which can also be infected by iridoviruses, occur (Jancovich et al. 1997), and human travel among breeding ponds is common. An irruption of chytridiomycosis or ranavirus in localized areas could threaten populations of plains leopard frogs as these diseases can be 100 percent fatal (Jancovich et al. 1997, Daszak et al. 1999). Steps should be taken to minimize this threat.

Introduced predatory fish remain a serious and well known threat to frog populations. Many agencies introduce such fish throughout the range of the plains leopard frog. This practice should be halted where the repercussions to amphibian populations could be significant. However, accidental or intentional introductions of predatory fish by the public will be difficult to guard against. Fish stocking should be re-evaluated to reduce predation pressure on frog populations and to guard against the introduction of lethal disease. A public information campaign to inform the public of the harm of accidental or intentional introduction of non-native predatory fish into ponds might help to reduce the frequency of these introductions. Under the National Forest Management Act, the USFS must undertake actions to preclude decline of species to the point that they may be considered threatened or endangered under the Endangered Species Act. We suggest that the elimination of fish stocking would be a powerful step towards maintaining viable, well-distributed populations of plains leopard frogs. It would also protect other species of frogs, many of which are also threatened by introduced fish.

Like the northern leopard frog (Smith and Keinath 2005), plains leopard frogs may use various mesic habitats, such as streamsides, riparian areas, and wet meadows for overland migration. It is probably important that these habitats be left relatively undisturbed if plains leopard frogs are to colonize new ponds, so that populations either grow or remain stable in any given locality. Skelly et al. (1999) showed that there was high turnover of northern leopard frog populations in a metapopulation in Michigan, and it is likely that this would be the case in other areas. This means that migration routes need to be maintained to ensure that frogs are able to colonize new breeding ponds or to recolonize ponds at which they have gone extinct in order to stabilize metapopulations and maintain metapopulation dynamics. Mesic habitats are probably also needed for summertime foraging.

Recent studies have shown that fish stocking seriously disrupts metapopulation dynamics in a variety of ranid frogs (Knapp and Matthews 2000, Pilliod and Peterson 2001, Knapp et al. 2003). In these studies it was found that *Rana muscosa* and *R. luteiventris* were eliminated from higher quality breeding habitat in permanent waters by introduced predaceous fish. Such fish can prey on all life stages of ranid frogs. When permanent waters are eliminated from the landscape, ranid frogs can become isolated in smaller, non-permanent ponds that may be poor quality breeding habitat. This results in declining populations and the loss of source habitats that have relatively high population growth. Isolation of ponds decreases the likelihood that frogs will immigrate into new breeding habitat. In essence, introduction of fish causes population declines due to habitat loss (loss of permanent water breeding sites) and due to fragmentation (loss of aquatic habitat that links each population to others across the landscape). In addition, in an area like Region 2, which is subject to long-term drought, a species like the plains leopard frog can be especially imperiled when semi-permanent ponds dry up during periods of drought. In such cases, permanent waters may be critical for species survival.

Implications and Conservation Elements

Habitat loss and fragmentation due to agricultural development likely have fragmented populations of plains leopard frogs across their range, leaving populations small and isolated. Given this fragmentation, it is likely that National Forest System lands are especially important to the survival of the species since the potential for relatively contiguous habitat still exists on these lands. However, introduced fish thrive in much of Region 2, and this can imperil frog ponds and drive local populations to extinction. In addition, introduced fish are vectors for diseases into frog breeding ponds, which may also cause local population extinctions. Introduction of non-native fish should be eliminated or minimized across Region 2 to halt predation on adult and larval frogs and to minimize the risk of introduction of exotic diseases.

Although migration corridors have not been studied in the plains leopard frog, many studies lead us to the conclusion that conservation of the plains leopard frog in Region 2 requires protection of an interconnected network breeding ponds and upland foraging habitats. Every effort must be made to keep migration corridors open. For the plains leopard frog, studies suggest that riparian areas are important movement corridors, but frogs may also move some distance over land. The movements of plains leopard frogs are too poorly known for us to further speculate on management actions that may assist migration in this species. However, it should be clear that habitat loss anywhere within the range, especially in wetlands and riparian areas, would place the frog at risk.

Prioritizing risk factors to plains leopard frogs in Region 2 is an uncertain enterprise since the species has been little studied. Much more is known about its congener, the northern leopard frog, so we might know more about risk factors in that species. However, even for this frog, little is known and it is difficult to prioritize risks (Smith and Keinath 2005). The following list is taken from Smith and Keinath (2005), and we have annotated the list as we feel is appropriate for the plains leopard frog. All of these factors have affected northern leopard frogs at certain study sites throughout North America.

Protection of known and potential breeding sites

Semlitsch and Bodie (1998) and Semlitsch (2000a) noted that breeding ponds that produced the highest density and biodiversity of amphibians (seasonal and semi-permanent ponds of <8 ha) are often left unprotected by law and ignored by management plans. It should also be noted that upland areas surrounding these ponds are used throughout the summer as foraging habitat and should also be protected (Semlitsch 1998, 2000b). For the plains leopard frog, which seems to be more tolerant of dry conditions than congeners, larger upland areas may need to be protected around breeding ponds. However, since nothing is known of movement patterns in this species, we can offer no concrete suggestions. We offer some guidelines for the northern leopard frog in Smith and Keinath (2005).

Degradation of wetland and surrounding upland habitats is unfavorable to the protection of frog populations. Although Semlitsch (1998) refers to upland habitat as a “buffer zone”, it is more appropriately referred to as “core habitat area” (Semlitsch personal communication 2001) and should be protected as such. Dole (1965a, 1965b) showed that northern leopard frogs typically used a home range of about 68 to 503 m^2. However, this does not indicate how much upland core area should be protected to conserve an entire population because some of the population will have home ranges farther from the breeding pond than other members. For the plains leopard frog, with a reputation for wandering further than northern leopard frogs, the core upland area may need to be larger.

Studies of Semlitsch (1998) on pond-breeding salamanders could be used as a start to protect upland core area for leopard frogs. Semlitsch (1998) reported that a "buffer zone" (i.e., core upland habitat) extending 164 m in all directions from each breeding pond is needed to conserve 95 percent of the adult breeding population of various pond-breeding salamanders foraging in the upland habitat following the breeding season. This core area is highly species-specific, however. The larger salamanders that Semlitsch (1998) studied are similar in mass to plains leopard frogs and use upland core areas of 150 to 200 m^2 surrounding breeding ponds. This might be taken as a general indication of the amount of upland core area needed by plains leopard frogs, but it is obviously highly speculative. Thorough studies are needed on plains leopard frogs for more definitive management recommendations.

Introduced predaceous fish

Predaceous fish have been clearly implicated in the decline of some frogs (Bovbjerg 1965, Brönmark and Edenhamn 1994, Hecnar and M'Closkey 1997) and are found throughout Region 2. Ongoing management by various agencies to maintain introduced predaceous fish throughout Region 2 makes it difficult to resolve the conflict between this priority and the need to protect populations of any species of frog. Fortunately, plains leopard frogs appear to be more tolerant of arid conditions and may use more temporary types of ponds in which to breed (Bragg 1950a). However, very little is known of their breeding biology and movement patterns, and management plans cannot be designed without natural history data. Many ponds are connected to waterways with introduced predaceous fish, and many ponds that are not connected to such waterways have introduced predaceous fish. Only with communication and cooperation among agencies involved in the management of these waters and introduced predaceous fish might it be possible to resolve conflicts between management for the production of introduced predaceous fish and any species of frog in Region 2.

Protection of overwintering sites

Northern leopard frogs use lakes, larger ponds, and streams in which to overwinter (Merrell 1977, Cunjak 1986). Plains leopard frogs have been reported to use similar habitat for overwintering (Collins 1993, Hammerson 1999). Overwintering mortality can be high at times in ranid frogs (Bradford 1983), and it is important that overwintering sites in Region 2 be identified and protected. Many of these sites are probably also stocked with introduced predaceous fish, which could easily decimate populations of frogs in the winter (Smith and Keinath 2005).

Water quality

Northern leopard frogs are clearly negatively affected by a variety of water quality issues, including the use of pesticides and fertilizers, grazing, and the drainage of mining waste into receiving waters and the resulting acidification of those waters and deposition of toxic metals and other constituents (Smith and Keinath 2005). We would assume that plains leopard frogs would be affected by the same issues, but suspect that pesticides, fertilizers, and grazing could be particularly important given the fact that plains leopard frogs occur in plains habitats where these factors are expected to be more prevalent. However, only three studies have been published on water quality and its effects on plains leopard frogs. Two of these studies are on the insecticide carbaryl (Bridges 1997, Boone and Semlitsch 2002). In both experiments, sublethal levels of carbaryl affected tadpole survival. Both Bridges (1997) and Boone and Semlitsch (2002) emphasized that sublethal levels of this insecticide affected tadpoles within one or two days, and that the effects interacted in complicated ways with other environmental factors, such as pond drying time (Boone and Semlitsch 2002). The unfortunate message from both of these studies is that pesticide effects are complex and act quickly. Even pesticides with short half-lives may not be safe around plains leopard frogs.

The third study to examine water quality and its effects on plains leopard frogs (Bruner et al. 2002) investigated landfill leachate, UV-B radiation, and how the two affected plains leopard frogs. They found that landfill leachate in concentrations of 10 and 25 percent killed frogs and that UV-B radiation had no effect on its own. However, UV-B radiation interacted with landfill leachate to reduce the rate of frog malformations caused by landfill leachate, as well as increase growth rate in the experiments.

Protection of migratory pathways

Like the northern leopard frog (Smith and Keinath 2005), the plains leopard frog stages long distance migrations (Collins 1993). However, the migration and movement patterns of plains leopard frogs have not been studied. It might be that plains leopard frogs would require relatively mesic environments to migrate through, similar to northern leopard frogs (Smith and Keinath 2005). If this is the case, management recommendations made by Smith and Keinath (2005) for the northern leopard frog might prove helpful in plains leopard frog management. We should note that deMaynadier and Hunter (1998) found that aquatic ranids were less affected by clearcutting than were the more terrestrial ranids, such as wood frogs (*Rana sylvatica*), and some salamanders. deMaynadier and Hunter (1998) thought that this was because the aquatic ranids were more dependent on aquatic habitat, while destruction of mesic terrestrial habitats had severe effects on the terrestrial ranids that frequently might use such habitats. The plains leopard frog might be considered a more terrestrial ranid frog.

Introduced infectious diseases

Amphibian population declines resulting from introduced infection diseases have been well studied, but the exact transmission vector is poorly known (Carey et al. 1999). Carey et al. (1999) noted that the introduction of exotics might spread disease. Since introductions of bullfrogs are common across the United States, it is possible that an introduction could cause additional damage by introducing chytridiomycosis, ranavirus, or a bacterial infection. Although tiger salamanders are native in many parts of Region 2, they are also commonly introduced in other parts of Region 2 as bait by anglers. Tiger salamanders are known to harbor iridoviruses (Daszak et al. 1999). Diseases could be introduced to Region 2 ponds through other means as well, such as tourists and investigators surveying and monitoring frog populations.

Road-related mortality

It has been known for some time that roads cause extensive mortality of juvenile northern leopard frogs (Bovbjerg and Bovbjerg 1964, Bovbjerg 1965, Merrell 1977). Recently, Ashley and Robinson (1996) showed that young-of-the-year northern leopard frogs were disproportionately represented among dead herpetofauna at their study site in Ontario. Carr and Fahrig (2001) found that traffic density within a 1.5 km radius of frog breeding ponds was negatively associated with the abundance of northern leopard frogs, suggesting that the viability of populations can be affected by road mortality. Road-associated factors such as sedimentation and runoff of toxic compounds can also affect aquatic communities near roads (Welsh and Ollivier 1998, Trombulak and Frissell 2000). The placement of new roads should be considered in relation to their effects on frog populations. In addition, frogs and their habitat should be considered when decisions are made to close or manage old roads.

Management Tools

Inventory and monitoring considerations

Basic inventories of the plains leopard frog have not been undertaken anywhere in Region 2 and virtually nowhere in the range of the species. It is somewhat remarkable to us that so little is known about this frog. It is critically important that inventories be undertaken, as it is nearly impossible to determine from the peer-reviewed literature whether this species is declining or in need of conservation attention. Of course, monitoring of plains leopard frogs within Region 2 could not begin without a comprehensive inventory of the species within Region 2, preferably with concomitant determination of effective population sizes at sites where frogs are found. These data should be entered into a GIS database.

Heyer et al. (1994) discussed techniques for surveying and monitoring amphibians. They and their contributors also discussed associated issues such as standardization and quantification, research design, data and planning of studies, estimation of population sizes, and data analysis. Of the survey and monitoring techniques discussed in Heyer et al. (1994), the following techniques could be useful in surveying, inventory, and monitoring of plains leopard frogs in Region 2:

- ❖ acoustic monitoring, i.e., call surveys (Berrill et al. 1992, Peterson and Dorcas 1994, Zimmerman 1994, Bishop et al. 1997, Bonin et al. 1997, Lepage et al. 1997, Johnson 1998, Mossman et al. 1998)
- ❖ drift fences and pitfall traps (Corn 1994, Dodd and Scott 1994)
- ❖ various quadrat sampling techniques (Jaeger 1994a, 1994b, Jaeger and Inger 1994)
- ❖ cover boards (Fellers and Drost 1994, Bonin and Bachand 1997, Davis 1997)

- visual encounter surveys (Crump and Scott 1994).

Spotlighting can be used at night to search for frog eyeshine (Fellers and Freel 1995). Various marking techniques can be used in conjunction with these survey methods to mark and track amphibians in the field (Dole 1972, Green 1992, Ashton 1994, Heyer 1994, Richards et al. 1994, Madison 1997, Madison and Farrand 1997, Semlitsch 1998).

Probably the simplest, least expensive, and most commonly used practice to inventory and monitor amphibian populations are call surveys (Berrill et al. 1992, Peterson and Dorcas 1994, Zimmerman 1994, Bishop et al. 1997, Bonin et al. 1997, Lepage et al. 1997, Johnson 1998, Mossman et al. 1998). Call surveys may be set up a number of ways, including traveling along transects randomized by habitat, at locations specified along a roadway (itself a kind of transect), and other methods. In the Black Hills region, the senior author has typically carried out call surveys by searching during daytime hours for ponds at which frogs may occur. There are many ways to search for appropriate ponds, including National Wetlands Inventory (NWI) maps, but the best way to search is usually by road and on foot once likely spots are found using NWI maps. Long-time residents or managers are also helpful in locating ponds. Then, starting about a half hour following sundown, investigators travel at night from potential breeding pond to potential breeding pond to listen for breeding choruses of frogs, recording choruses, and sometimes estimating the size of the chorus. However, chorus estimates are typically very rough without actually catching and counting the frogs, which is very time consuming. Typically, it is not necessary to work much past midnight. Ponds are usually visited at least three times during the breeding season to verify whether the ponds without choruses are being used as chorusing sites. Depending on the species, call surveys can be an excellent way to survey and monitor frogs.

Although some call surveys have been quite successful as survey and monitoring efforts, not all anurans are easily surveyed, and the calls of some frog species vary in volume geographically. For example, Bishop et al. (1997) noted that northern leopard frogs have low volume calls that may be hard to hear. Bonin et al. (1997) have also advised against the use of the technique to quantitatively assess the extent of frog declines over several years. Before auditory techniques, such as audio strip transects (Zimmerman 1994), breeding site surveys (Scott and Woodward 1994), automated data loggers (Peterson and Dorcas 1994) or basic acoustic monitoring (Rand and Drewry 1994), are used for ongoing monitoring, these techniques should be evaluated for their efficacy in Region 2.

Drift fences and pitfall traps can be installed and periodically monitored to assess the abundance of amphibians at a study site (Corn 1994). Drift fences can also be installed at breeding sites, completely encircling the site and trapping every individual that enters or leaves (Dodd and Scott 1994). Drift fences are long fences made of sheet metal and placed flush to the ground such that amphibians cannot climb over or burrow under the fence. Pitfall or funnel traps are placed along the fence to trap amphibians moving along the fence. In the experience of the senior author it can be difficult to train non-herpetologists to properly install drift fences, and we recommend that a herpetologist be consulted and survey teams be trained if drift fences are to be used at any ponds to survey plains leopard frogs. The primary use of drift fences would be for studies of plains leopard frog breeding ponds or studies of movement in the species. Drift fences can be costly, both in terms of materials and construction effort. However, once installed drift fences can be cheaply and easily operated.

Upland habitats can be quantitatively sampled using quadrat sampling (Jaeger and Inger 1994), transect sampling (Jaeger 1994a), and patch sampling (Jaeger 1994b). Each of these techniques relies on sampling various sizes and shapes of plots to determine how many amphibians occur per unit area of sampled habitat. Of all the techniques we have discussed, these are the only techniques that can provide information on the number of animals per unit of habitat. However, the senior author has frequently experienced extremely low capture rates in plains habitats, and the technique could be very time consuming if large samples are needed.

Patch sampling (Jaeger 1994b) refers to the sampling of patches where frogs are more likely to occur, which in the case of plains leopard frogs would be habitat near breeding ponds, along streams, or in riparian corridors. A major drawback to patch sampling is that the habitat is not randomly sampled; habitats that investigators think lack frogs are not sampled. However, as long as the data are properly reported and not presented as being a random sample of all possible habitats, patch sampling is an appropriate tool that can be used to survey amphibians. The senior author has frequently conducted patch sampling in plains habitats because of the low capture efficiency of random sampling methods in this habitat type.

Patch sampling can be combined with quadrat or transect sampling. During the breeding season, plains leopard frogs are concentrated at ponds, but following breeding they are dispersed in upland habitat and may be difficult to locate. Of course, it might be expected that frogs will be found closer to ponds, streams, or riparian areas at this time. Therefore, areas near ponds, streams, and in riparian strips can be used as patches in which to place sampling sites to assess plains leopard frog abundance following the breeding season. To systematically sample these areas, researchers might restrict searches to areas immediately adjacent to ponds (for example, within 200 m of ponds), along streams, and in riparian corridors. They can then conduct quadrat or transect samples (quadrats are square plots while transects are basically long strip-like plots; some researchers make little distinction between the two) in these patches to assess the numbers of adult frogs using these habitats. These techniques could be used to assess frog density around breeding ponds, along streams, and in riparian corridors following the breeding season.

Most herpetologists have long known that many amphibians take refuge under various objects, and trash piles are frequently coveted areas in which to search for specimens. Cover boards are objects such as plywood boards of specific sizes that are placed in the environment as a method of quantitatively surveying amphibians (Fellers and Drost 1994). They are probably best used for salamanders and snakes and have not been validated for use with plains leopard frogs. The technique has proven useful to monitor salamander populations, but there are differences in how species use cover boards and the types of cover boards favored by different species (Bonin and Bachand 1997, Davis 1997). Construction techniques and suggested arrays can be found in Bonin and Bachand (1997) and Davis (1997). Cost would be minimal following initial testing and construction of cover boards. Unlike drift fences, cover boards could be left in place unmonitored for long periods of time since specimens can use cover boards at will and are not trapped in pitfalls or funnel traps that cause rapid desiccation.

Another relatively simple way of surveying for frogs are nocturnal surveys using spotlights (Fellers and Freel 1995). In these surveys, investigators use a bright searchlight (the authors recommend a 250,000-candle power light) to search for frog eyeshine. They also recommend that investigators use binoculars and rest them on the light so that both move in unison to search for frogs. Eyeshine from spiders and reflection of raindrops can be confused with frog eyeshine, but practice at the technique makes it relatively easy to distinguish frogs from these kinds of reflections.

Any technique that allows the hand capture of specimens can be used in conjunction with marking techniques as part of a larger study on breeding or movement patterns. Amphibians can be marked and tracked using a variety of devices including thread bobbins (Heyer 1994), radiotransmitters (Richards et al. 1994), radioactive tags (Ashton 1994), toe clipping (Green 1992), and passive integrated transponder (PIT) tags.

Thread bobbins have been used to track northern leopard frogs (Dole 1972), and the technique could be used on plains leopard frogs. The device is a spool of thread attached to a harness that is tied around the body of the frog just ahead of the hind legs. It can be used to track frogs over short distances of up to 50 m (Heyer 1994). The technique is somewhat time-consuming but inexpensive, and it can provide basic information on the movements of frogs in the field (Dole 1972). There are occasional harmful effects of the harness as the frogs can become entangled in the string or the harness can irritate the frog (Dole 1972).

Radiotracking has been used on larger animals for a number of years, but with the miniaturization of transmitters within the last ten years it has been successfully used on amphibians in the field, including with ranid frogs (Rathbun and Murphey 1996, Lamoureux and Madison 1999, Mathews and Pope 1999, Bull 2000, Bull and Hayes 2001, Waye 2001). The technique is time-consuming, expensive, requires detailed training of investigators, and also may require invasive surgery to install transmitters. However, it is the best way to obtain detailed information on the movement of animals in the field.

Radioactive tags have also been used to monitor amphibian movements in the field (Ashton 1994) and have been used in salamanders for several years (Semlitsch 1998). Radioactive tags are particularly useful for small organisms that cannot be tracked using radiotransmitters. The tags can be detected by scintillation counters up to 5 m (Semlitsch 1998). The technique can be used to monitor amphibian movements, but there are concerns over handling of the tags, health effects on frogs with implanted tags, and effects to the environment.

Toe clipping has long been used to mark various animals in the field and could be used to track plains leopard frogs over time. A basic pattern for numbering frogs using toe clipping is outlined by Green (1992). In conjunction with other sampling techniques, toe clipping can be used to monitor the movements of individuals and can be used to derive a mark-recapture estimate of population density using a number of open population estimators given in Krebs (1999). Deriving a mark-recapture estimate of population size at most ponds would probably require marking and recapture of large numbers of frogs and would be time consuming. Since toe clipping is invasive, it should not be used unless it is part of a determined effort to monitor frog movements or to derive population estimates. Toe clipping, when done in conjunction with basic sampling, is simple and inexpensive to implement.

Individual plains leopard frogs may be identifiable through unique markings. Robert Newman (personal communication 1997) has identified a number of wood frogs using computer analysis of photographs of unique patterns on their back. The spotted pattern across the back of plains leopard frogs might serve to uniquely identify individuals should an intensive study of population sizes or movements be undertaken at certain sites. The technique is time consuming, and management of the individual records could be difficult. Attempting to discern one frog from another using specific markings could be difficult or impossible. We are not aware of anyone that has attempted such a study in plains leopard frogs.

Finally, passive integrated transponder (PIT) tags can be used to mark individuals as well. These are small glass rods, usually no more than 10 mm in length, that are inserted under the skin of individuals. When waved over a marked individual, a device reads a uniquely coded number from the tag. Such tags have been used for several years to mark Jemez Mountain salamanders (*Plethodon neomexicanus*), a slim and small salamander found in the United States, with a snout-vent length of only 4.7 to 6.5 cm (Painter personal communication 2000). They would probably work to mark plains leopard frogs as well, again as part of a detailed movement or population study. They and the reader are not expensive to purchase and are much less expensive than radiotransmitters without the safety issues associated with radioactive tags. However, PIT tags are invasive to install since they must be inserted into the abdomen of animals.

Herpetologists for many years have simply walked around and looked in suitable habitat for amphibians. This is frequently the most productive way to search for amphibians, and if properly quantified (e.g., by keeping track of the amount of time spent searching), this is a suitable technique to survey and monitor many species (Crump and Scott 1994). Crump and Scott (1994) called the technique a visual encounter search. Investigators simply approach a survey area and walk around the area searching for the species of interest, usually flipping suitable cover objects. After a pre-determined period of time, the search is halted and results (number of specimens encountered) recorded. The senior author has used this technique in plains habitats with some success. Typically a three or four person crew is used, and a two person-hour search is conducted at each survey site. The time is derived by using a three person crew for 40 minutes (3 persons by 40 minutes = 2 person-hours) or a four person crew for 30 minutes (4 persons by 30 minutes = 2 person-hours). Crump and Scott (1994) covered the assumptions and limitations of this technique and provided a sample data sheet. Smith and Keinath (2005) assessed the usefulness of this technique for northern leopard frogs.

Another survey method useful in monitoring frogs is egg mass surveys (Corn and Livo 1989, Werner et al. 1999, Crouch and Paton, 2000). In this type of survey, investigators visit ponds that are suspected to have breeding populations of plains leopard frogs to search for their egg masses. As in northern leopard frogs (Smith and Keinath 2005), these are laid in clumps on submerged vegetation slightly below the water surface and may be found by trained investigators. Since each clump is laid by a single female, simply counting all the egg masses found in a pond gives an estimate of the number of females using the pond for reproduction. If a 1:1 sex ratio is assumed, the total breeding population size could be determined, but it is important to recognize that not all females may breed during a given year, the sex ratio may not be 1:1, and there would be an undetermined number of sexually immature individuals in the population. It might be difficult for non-specialists to identify plains leopard frog eggs. It would also not be possible to determine the effective population size since many males may not breed successfully during any given year.

Aquatic funnel trapping is a presence/absence technique that can be used to detect frog tadpoles in breeding ponds. Various types of funnel traps are described in Adams et al. (1997). These traps are placed in ponds, where tadpoles swim into them and are captured. The traps are checked on a frequent basis and tadpoles are identified and released. The materials used are not expensive (minnow traps and even used two-liter plastic soda bottles can be used for the purpose), but they need to be checked daily or every few days during the tadpole season. Non-specialists may find it difficult to differentiate the various tadpoles found in Region 2.

Instituting an inventory and monitoring program in Region 2

In Smith and Keinath (2005), the lead author developed a basic program designed to inventory and monitor any size of National Forest System lands, from the district to the entire region, depending on funding available and purposes of the agency. This section is reprinted in its entirety in **Appendix B**, since the design and techniques are identical, no matter which species of anuran is under study.

Population and habitat management

Few papers have addressed management concerns for amphibians, fewer still have looked at ranid frog management, and none have done so specifically for plains leopard frogs. Semlitsch (2000a) is the most extensive review of the amphibian management literature available, and deMaynadier and Hunter (1995) have reviewed forest management practices and their effect on amphibians in North America. However, Lannoo (1998b) has provided perhaps the most succinct summation of a potentially successful strategy for conservation of frog populations in North America. Modified for plains leopard frogs in Region 2, his advice might be to provide a series of seasonal or semi-permanent ponds that are connected by upland migration corridors plus habitat for terrestrial life history stages (the upland core areas advocated by Semlitsch, 1998 and 2000b).

To briefly summarize the findings of deMaynadier and Hunter (1995), we can conclude that several standard forestry practices can adversely affect populations of amphibians in general and probably have some effect on plains leopard frogs. Many of their recommendations cover timbering operations, which appear to us to be less important in the lowland areas where plains leopard frogs should occur in Region 2. What is relevant, however, are the most important variables correlated with amphibian abundance, which appeared to be microhabitat variables such as herbaceous cover, downed wood, litter depth, and other such variables. Amphibians better tolerate habitats that provide cover because these habitats allow them to avoid desiccation. Therefore, where appropriate, understory disturbance should be minimized. Scattering this type of disturbance around the landscape is probably beneficial (i.e., cause disturbance in smaller patches where possible). Secondly, riparian corridors are used as migration pathways by several amphibians, and we can expect that the wider they are and the more connected frog breeding ponds are to these riparian zones, the better off populations of frogs will be. Third, roadways can isolate populations or reduce their size, sometimes even if these roadways are low or no-use roadways. This might be less of a problem for the plains leopard frog, a species that appears to migrate long distances under less than ideal conditions. Finally, the few data that we currently have on prescribed burning have shown that amphibians sometimes tolerate prescribed burning rather well. However, all these conclusions are largely based on types of amphibians other than ranid frogs and remain to be tested in this group.

Semlitsch (2000b) has provided a wider-ranging review of various management practices that is less focused on specific types of forestry practices. He identifies several threats to local and regional amphibian populations including habitat destruction and alteration, global climate change, chemical contamination, disease, invasive species, and commercial exploitation. Among this group we have already discussed the threats that pertain to Region 2 populations of plains leopard frogs, namely habitat destruction, chemical contamination, diseases, and particularly invasive species (introduced predaceous fish). Yet to be discussed in this report is the importance of local population dynamics and metapopulation dynamics as emphasized by Semlitsch (2000b).

Like many species, pond-breeding amphibian populations are connected across the landscape, with each pond serving as a population and all the populations of all the ponds existing as one, or several, metapopulations. Each pond may be more or less isolated, depending on how far it is from other ponds, the predilection of plains leopard frogs to migrate from pond to pond, the tendency of young to disperse from natal ponds, and the philopatry of subadult and adult frogs. Without detailed studies of the genetics and movement patterns of the frogs, it is difficult to know whether there is a high degree of within-population genetic variability (i.e., whether most genetic variability is found within a population or pond), or a high degree of among-population genetic variability (i.e., most genetic variability is found among ponds). In the former case, conservation of one or a few breeding ponds and surrounding upland habitat conserves most of the genetic variability within the metapopulation. In the latter case, several ponds must be conserved to maintain a high degree of genetic diversity within the metapopulation.

Of course, the safest way to manage to conserve high genetic diversity is to maintain as many ponds and their surrounding upland core area as possible with as many migration corridors among them as possible.

Earlier we discussed the detrimental effects cattle grazing can have on frog populations. We suggest fencing off breeding ponds and important feeding habitats and riparian movement corridors, where possible, to limit access by cattle. Stock tanks outside of fenced ponds could be used to water cattle. Unfortunately, the breeding season in plains leopard frogs appears to be spread out through the year, making it more difficult to keep cattle out of breeding ponds by rotating cattle into pastures without ponds during frog breeding season.

Captive propagation and reintroduction

Captive propagation and reintroduction in herpetological conservation has a mixed history. A recent success is documented by Sexton et al. (1998), who reported that reintroduced wood frogs began expanding into formerly occupied habitat at sites in Missouri. However, a recent reintroduction of boreal toads (*Bufo boreas*) into Rocky Mountain National Park was a failure (Muths et al. 2001). Dodd and Seigel (1991) document many such failures from the herpetological literature. Smith and Keinath (2005) discussed the history of a reintroduction of northern leopard frogs in Alberta, Canada. This project was clearly time consuming and costly. Prevention of declines before they occur, or prevention of further declines, is clearly preferable to reintroduction attempts.

Information Needs

Overall, the paucity of data indicates that survey and inventory work are needed throughout the range of this species, and data are needed on virtually all aspects of its natural history.

Survey and monitoring

There do not appear to have been any surveys of plains leopard frogs in Region 2, or in much of the range of the species. It is critical that baseline data are obtained to assess the abundance of plains leopard frogs throughout Region 2 and begin tracking population trends. Many of the information needs identified in this report cannot be completed before basic surveys have been conducted. Heyer et al. (1994), Olson et al. (1997), and suggestions in this report can be used to institute a survey program throughout Region 2.

Mapping of habitat

Plains leopard frog habitat has not been mapped throughout Region 2. Plains leopard frogs probably need seasonal and semi-permanent ponds that are <5 ha in size, about the size discussed by Semlitsch and Bodie (1998) and Semlitsch (1998, 2000a, 2000b) for other pond-breeding amphibians, but this is not known for certain. Plains leopard frogs need to be found in Region 2, habitat described at some basic level, and surveys initiated. As discussed by Smith and Keinath (2005), there appears to be no substitute for ground surveys of appropriate frog breeding habitat. However, appropriate frog breeding habitat has not even been properly described for plains leopard frogs. When found, breeding ponds need to be located using GPS and then downloaded into an appropriate GIS system to find these ponds in the future and track presence and absence of frogs at these sites over time.

Characterization of habitat

As discussed above, plains leopard frog habitat has not been characterized at any level. In addition, little or nothing appears to be known about the types of ponds used for breeding, habitats used for overwintering, or upland sites used for foraging or migration. A good herpetologist may be able to guide a mapping team to "good" plains leopard frog habitat, but this information has not been published. Unfortunately, mapping needs to be completed and habitat models need to be developed to guide conservation efforts, and even to initiate basic surveys. These types of data are needed to develop any habitat management plan (as envisioned by Semlitsch 2000b) for the plains leopard frog in Region 2.

Overwintering habitat

Studies of overwintering sites can be difficult to undertake. Cunjak (1986) relied on SCUBA techniques to study northern leopard frogs overwintering in streams in Ontario while Merrell (1977) relied on simple but careful visual observations early in spring and late in the fall to report on frogs entering and leaving overwintering sites. Currently we know nothing about plains leopard frog overwintering sites in Region 2. Radiotracking could also be useful in identifying overwintering sites, but it would be expensive and require expert study.

Studies of frog movements

Movement studies are probably the most time-intensive and difficult field studies to conduct on amphibians. They would, however, give us detailed information on how the habitat is used by plains leopard frogs that may be difficult to obtain any other way. They would also address two critical questions: How much upland habitat is needed to conserve 95 percent of the frog population at a particular breeding pond (i.e., how much core upland habitat to protect around each pond)? What habitat features are used for migration by subadult and adult plains leopard frogs (i.e., how to protect migration corridors used by frogs)?

Marking technology would probably limit these studies. High technology marking techniques, such as radiotracking, are expensive but reveal detailed movement patterns relatively quickly, unlike any other technique. Radiotracking is time and technology intensive and requires advanced training. We favor passive integrated transponders since they are easily inserted, simple to use in the field, and are being used extensively in herpetological studies with few adverse health effects noted. Radioactive tagging can be used but can be problematic for the researcher, the environment, and the frogs. Toe clipping is a time-tested inexpensive technique that can also be used, but may cause adverse health effects for the frogs. Individual markings of the frogs themselves could be used, but the computer technology needed for this technique would need further development. Regardless of the marking technique to be used, time and effort are required to mark and recapture large numbers of northern leopard frogs. However, it is critical to the management of plains leopard frogs that core upland habitats and migration corridors used by the frogs be delineated and conserved.

As a side benefit, movement studies conducted over numerous years would give information on the basic demography of populations. Another benefit to movement studies is that they could be combined with studies of other issues in plains leopard frog conservation, including timber practices, burning, the effects of roads, and overwintering, and in fact are critical in studies of most of these potential conservation issues.

Disease and limb malformations

Any potential disease outbreaks should be carefully noted and investigated. Red leg presents itself as a reddish rash on the inside of the thighs and can result in death. The symptoms of several other diseases are drooping posture or a moribund state, difficulty of righting or movement or complete lack of a righting response, or mortality. Determination of the presence of disease would have to be made by a qualified wildlife disease specialist. Investigators whose works are cited in the "Community Ecology; Parasites and Diseases" section should be alerted and consulted. Any large kills of plains leopard frogs should be reported (these could represent death by disease or by chemicals). Pesticides used in Region 2 should be investigated, especially if large amounts will be used to combat disease or pest outbreaks. Any limb malformations observed in Region 2 should be reported to an appropriate biologist in charge of the affected district, to the authors, to state game departments, and especially to the limb malformations website maintained by the Northern Prairie Wildlife Research Center (1997).

Effect of introduced predaceous fish

Sport fishing is a large industry throughout Region 2, and it is unlikely to diminish in importance. It can be assumed that management agencies will continue to manage for the presence of sport fish that are predators on various life stages of the plains leopard frog. The industry depends on predaceous fish that have been introduced throughout Region 2. Therefore, it can be assumed that plains leopard frogs have not evolved a natural defense against these predators and that some of their life history strategies put them at risk from these predators. All life stages are probably vulnerable, but there may be certain life stages that are more subject to predation than others. Some unanswered questions are: Are eggs and tadpoles more vulnerable to predation by introduced predaceous fish than subadult and adult frogs? What types of introduced fish are most likely to eat which life history stages? Are frogs likely to suffer predation during the overwintering period? Do frogs overwinter in habitats that are also used by introduced predaceous fish? Is predation by introduced predaceous fish ameliorated in certain types of habitats, and can introduced fish be kept out of these habitats? Given the likelihood that management objectives for plains leopard frogs will continue to clash with management objectives for sport fishing, it is imperative that management agencies devise innovative and collaborative means of managing for these two conflicting objectives. Smith and Keinath (2005) have provided a list of prospective studies on the effects of predaceous fish on the northern leopard frog; we would suggest the same sorts of studies for plains leopard frogs.

Effect of roadways

Wyman (1991) showed that roadways caused heavy mortality in some amphibian populations. However, the results of deMaynadier and Hunter (1995) showed that this is not necessarily the case, depending on the road type. Nevertheless, we would recommend a reduction of roadways in Region 2. It would be logical to combine movement studies with a study of the effect of roadways by picking a few breeding ponds near different types of roads as study sites. If done in combination with a broader study on the movement of northern leopard frogs a study on road effects would simply represent value added to a current study and would not cost anything beyond funds spent on the larger movement study.

Genetic studies

It would be relatively easy to collect frogs from several sites across Region 2, sample small pieces of tissue (this should not increase mortality or morbidity of the frogs as very small amounts of tissue are needed), and subject them to genetic analysis. However, the genetic data needed are very fine-grained and require considerable expertise and funding to obtain. Such data would be invaluable and could tell us the extent of philopatry at specific ponds, the extent of genetic connectedness of each pond, and whether there is high within- or among – site genetic variation in plains leopard frogs in Region 2. These data can be used to guide management strategies by telling us something about ponds needing conservation attention (for example, which ponds serve as sources for colonization) and the extent and direction of movement of frogs from pond to pond.

Prescribed fire and fire suppression

The effects of fire on plains leopard frog populations should be investigated. This could be done either opportunistically, for example by tracking frog populations within recently burned areas, or through studies that specifically address the effects of a prescribed fire regime on plains leopard frog populations. In the latter case, studies on some other aspect of frog biology, such as frog movements, could be modified by placing study sites within areas under prescribed burn regimes and in areas in which fire is suppressed. The study sites in both study areas could then be compared. Again, such a study would represent value added to an ongoing study while costing relatively little additional funding to implement.

References

Adams, M.J., K.O. Richter, and W.P. Leonard. 1997. Surveying and monitoring amphibians using aquatic funnel traps. Pages 47-54 *in* D.H. Olson, W.P. Leonard, and R.B. Bury, editors. Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Northwest Fauna No. 4.

Ashley, E.P. and J.T. Robinson. 1996. Road mortality of amphibians, reptiles, and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field-Naturalist 110:403-412.

Ashton, R.E., Jr. 1994. Tracking with radioactive tags. Pages 158-166 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Baker, M.R. 1985. *Raillietnema longicaudata* (Walton, 1929) n. comb. (Nematoda: Cosmocercidae) from North American frogs. Proceedings of the Helminthological Society of Washington 52:76-79.

Baness, E. 1997. The distribution and hybridization of the leopard frogs, *Rana pipiens* and *Rana blairi* in Iowa. M.S. Thesis, Drake University, Des Moines, IA.

Beauvais, G.P. and R. Smith. 2005. Predictive distribution maps for 54 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Report prepared for the U.S. Geological Survey-National Gap Analysis Program by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, WY.

Beauvais, G.P., R. Thurston, and D. Keinath. 2003. Predictive range maps for 15 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Report prepared for the U.S. Geological Survey-National Gap Analysis Program by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, WY.

Berger, L., R. Speare, P. Daszak, D.E. Green, A.A. Cunningham, C.L. Gogging, R. Slocombe, M.A. Ragan, A.D. Hyatt, K.R. McDonald, H.B. Hines, K.R. Lips, G. Marantelli, and H. Parkes. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Sciences 95:9031-9036.

Berrill, M., S. Bertram, D. Brigham, and V. Campbell. 1992. A comparison of three methods of monitoring frog populations. Pages 87-93 *in* C.A. Bishop and K.E. Pettit, editors. Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy. Occasional Paper Number 76, Canadian Wildlife Service, Ottawa, Ontario, Canada.

Bishop, C.A., K.E. Pettit, M.E. Gartshore, and D.A. MacLeod. 1997. Extensive monitoring of anuran populations using call counts and road transects in Ontario (1992 to 1993). Pages 149-160 *in* D.M. Green, editor. Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number One. Society for the Study of Amphibians and Reptiles, Saint Louis, MO.

Bonin, J. and Y. Bachand. 1997. The use of artificial covers to survey terrestrial salamanders in Québec. Pages 175-179 *in* D.M. Green, editor. Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number One. Society for the Study of Amphibians and Reptiles, Saint Louis, MO.

Bonin, J., M. Ouellet, J. Rodrigue, J.L. DesGranges, F. Gagné, T.F. Sharbel, and L.A. Lowcock. 1997. Measuring the health of frogs in agricultural habitats subjected to pesticides. Pages 246-257 *in* D.M. Green, editor. Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number One. Society for the Study of Amphibians and Reptiles, Saint Louis, MO.

Boone, M.D. and R.D. Semlitsch. 2002. Interactions of an insecticide with competition and pond drying in amphibian communities. Ecological Applications 12:307-316.

Bovbjerg, R.V. 1965. Experimental studies on the dispersal of the frog, *Rana pipiens*. Proceedings of the Iowa Academy of Science 72:412-418.

Bovbjerg, R.V. and A.M. Bovbjerg. 1964. Summer emigrations of the frog *Rana pipiens* in northwestern Iowa. Proceedings of the Iowa Academy of Science 71:511-518.

Bradford, D.F. 1983. Winterkill, oxygen relations, and energy metabolism of a submerged dormant amphibian, *Rana muscosa*. Ecology 64:1171-1183.

Bragg, A.N. 1944. Egg laying in leopard frogs. Proceedings of the Oklahoma Academy of Sciences 24:13-14.

Bragg, A.N. 1950a. Observations on the ecology and natural history of Anura. XVII. Adaptations and distribution in accordance with habits in Oklahoma. Research on the Amphibians of Oklahoma, University of Oklahoma Press, Norman, OK. Pages 59-100.

Bragg, A.N. 1950b. Salientian breeding dates in Oklahoma. Research on the Amphibians of Oklahoma, University of Oklahoma Press, Norman, OK. Pages 35-38.

Bragg, A.N. and V.E. Dowell. 1954. Leopard frog eggs in October. Proceedings of the Oklahoma Academy of Sciences 35:41.

Bridges, C.M. 1997. Tadpole swimming performance and activity affected by acute exposure to sublethal levels of carbaryl. Environmental Toxicology and Chemistry 16:1935-1939.

Brodman, R., S. Cortwright, and A. Resetar. 2002. Historical changes of reptiles and amphibians of northwest Indiana fish and wildlife properties. American Midland Naturalist 147:135-144.

Brönmark, C. and P. Edenhamn. 1994. Does the presence of fish affect the distribution of tree frogs (*Hyla arborea*)? Conservation Biology 8:841-845.

Brown, L.E. 1992. *Rana blairi*. Pages 536.1-536.6 *in* Catalog of American Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles, St. Louis, MO.

Bruner, M.A., P.A. Shipman, M. Rao, and J.A. Bantle. 2002. Developmental effects of ambient UV-B light and landfill leachate in *Rana blairi* and *Hyla chrysoscelis*. Ecotoxicology and Environmental Safety 53:73-80.

Buckhouse, J.C. and G.F. Gifford. 1976. Water quality implications of cattle grazing on a semi-arid watershed in southeastern Utah. Journal of Range Management 29:109-113.

Bull, E.L. 2000. Comparison of two radio transmitter attachments on Columbia spotted frogs (*Rana luteiventris*). Herpetological Review 31:26-28.

Bull, E.L. and M.P. Hayes. 2001. Post-breeding season movements of Columbia spotted frogs (*Rana luteiventris*) in northeastern Oregon. Western North American Naturalist 61:119-123.

Bureau of Land Management Colorado State Office. 2000. State director's senstitive species list. Information Bulletin No. CO-2000-014 (April 14, 2000). USDI Bureau of Land Management, Colorado State Office, Lakewood, CO.

Caldwell, J. and G. Glass. 1976. Vertebrates of the Woodson County State Fishing Lake and Game Management Area. Pages 62-76 *in* Preliminary inventory of the biota of Woodson County State Fishing Lake and Game Management Area, J. Caldwell, editor. Report of the State Biological Survey of Kansas 5:1-76.

Carey, C. 1993. Hypothesis concerning the causes of the disappearance of boreal toads from the mountains of Colorado. Conservation Biology 7:355-362.

Carey, C., N. Cohen, and L. Rollins-Smith. 1999. Amphibian declines: An immunological perspective. Developmental and Comparative Immunology 23:459-472.

Carr, L.W. and L. Fahrig. 2001. Effect of road traffic on two amphibian species of differing vagility. Biological Conservation 15:1071-1078.

Christiansen, J.L. 2001. Non-native amphibians and reptiles in Iowa. Journal of the Iowa Academy of Sciences 108: 210-211.

Christiansen, J.L. and R.M. Bailey. 1991. The Salamanders and Frogs of Iowa. Iowa Department of Natural Resources Nongame Technical Series 3:1-24.

Clarkson, R.W. and J.C. Rorabaugh. 1989. Status of leopard frogs (*Rana pipiens* complex: Ranidae) in Arizona and southeastern California. Southwestern Naturalist 34:531-538.

Collins, J.T. 1993. Amphibians and Reptiles in Kansas. Third edition. The University of Kansas Natural History Museum, Lawrence, Kansas, USA. Nature in Kansas Series No. 13.

Colorado Division of Wildlife. 2003. Colorado listing of Endangered, Threatened, and Wildlife Species of Special Concern: April 2003 update. Colorado Division of Wildlife, Denver, CO. (Available: http://wildlife.state.co.us/species_cons/list.asp).

Conant, R. and J.T. Collins. 1991 A Field Guide to Reptiles and Amphibians: Eastern and Central North America. Third edition. Houghton Mifflin Company, Boston, MA.

Corn, P.S. 1994. Straight-line drift fences and pitfall traps. Pages 109-117 *in* W.R.Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayak, and M. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Corn, P.S. and L.J. Livo. 1989. Leopard frog and wood frog reproduction in Colorado and Wyoming. Northwestern Naturalist 70:1-9.

Cousineau, M. and K. Rogers. 1991. Observations on sympatric *Rana pipiens*, *R. blairi*, and their hybrids in eastern Colorado. Journal of Herpetology 25:114-116.

Crawford, J.A., L.E. Brown, and C.W. Painter. 2005. *Rana blairi*. Pages 532-534 *in* M. Lannoo, editor. Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.

Crouch, W.B. and P.W. C. Paton. 2000. Using egg-mass counts to monitor wood frog populations. Wildlife Society Bulletin 28:895-901.

Crump, M.L. and N.J. Scott, Jr. 1994. Visual encounter surveys. Pages 84-92 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayak, and M. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Cunjak, R.A. 1986. Winter habitat of northern leopard frogs, *Rana pipiens*, in a southern Ontario stream. Canadian Journal of Zoology 64:255-257.

Cunningham A.A., T.E.S. Langton, P.M. Bennett, J.F. Lewin, S.E.N. Drury, R.E. Gough, and S.K.MacGregor. 1996. Pathological and microbiological findings from incidents of unusual mortality of the common frog (*Rana temporaria*). Philosophical Transactions of the Royal Society of London 351:1539-57.

Daszak, P., L. Berger, A.A. Cunningham, A.D. Hyatt, D.E. Green, and R. Speare. 1999. Emerging infectious diseases and amphibian population declines. Emerging Infectious Diseases 5:735-748.

Daszak, P., A.A. Cunningham, and A.D. Hyatt. 2000. Emerging infectious diseases of wildlife: Threats to biodiversity and human health. Science 287:443-449.

Davis, T.M. 1997. Non-disruptive monitoring of terrestrial salamanders with artificial cover objects on southern Vancouver Island, British Columbia. Pages 161-174 *in* D.M.Green, editor. Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation, Number One. Society for the Study of Amphibians and Reptiles, Saint Louis, MO.

Degenhardt, W.G., C.W. Painter, and A.H. Price. 1996. Amphibians and Reptiles of New Mexico. University of New Mexico Press, Albuquerque, NM.

deMaynadier, P.G. and M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: A review of the North American literature. Environmental Review 3:230:261.

deMaynadier, P.G. and M.L. Hunter, Jr. 1998. Effects of silvicultural edges on the distribution and abundance of amphibians in Maine. Conservation Biology 12:340-352.

Dixon, J.R. 2000. Amphibians and Reptiles of Texas. Second edition. Texas A & M University Press, College Station, TX.

Dodd, C. K., Jr., and D. E. Scott. 1994. Drift fences encircling breeding sites. Pages 125-141 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Dodd, C.K., Jr. and R.A. Seigel. 1991. Relocation, repatriation, and transolocation of amphibians and reptiles: Are they conservation strategies that work? Herpetologica 47:336-350.

Dole, J.W. 1965a. Spatial relations in natural populations of the leopard frog, *Rana pipiens* Schreber, in northern Michigan. American Midland Naturalist 74:464-478.

Dole, J.W. 1965b. Summer movement of adult leopard frogs, *Rana pipiens* Schreber, in northern Michigan. Ecology 46:236-255.

Dole, J.W. 1972. The role of olfaction and audition in the orientation of leopard frogs, *Rana pipiens*. Herpetologica 28:258-260.

Duellman, W.E. and L. Trueb. 1986. Biology of Amphibians. McGraw-Hill, Inc. New York, NY.

Dunlap, D.G. and K.C. Kruse. 1976. Frogs of the *Rana pipiens* complex in the northern and central plains states. Southwestern Naturalist 20:559-571.

Durnin, K.B. and G.R. Smith. 2001. Effects of changing water volume on the tadpoles of two anuran species (*Pseudacris triseriata* and *Rana blairi*). Journal of Freshwater Ecology 16:411-414.

Ehrlich, D. 1979. Predation by bullfrog tadpoles (*Rana catesbeiana*) on eggs and newly hatched larva of the plains leopard frog (*Rana blairi*). Bulletin of the Maryland Herpetological Society 15:25-26.

Elmore, W. and R.L. Beschta. 1987. Riparian areas: Perceptions in management. Rangelands 9:260-265.

Faeh, S.A., D.K. Nichols, and V.R. Beasley. 1998. Infectious diseases of amphibians. Pages 259-265 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Fellers, G.M. and C.A. Drost. 1994. Sampling with artificial cover. Pages 146-150 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Fellers, G.M. and K.L. Freel. 1995. A Standardized Protocol for Surveying Aquatic Amphibians. National Park Service Technical Report NPS/WRUC/NRTR-95-01.

Gillis, J.E. 1975. Characterization of a hybridizing complex of leopard frogs. Ph.D. dissertation, Colorado State University, Fort Collins, CO.

Gillis, J.E. 1979. Adaptive differences in the water economics of two species of leopard frogs from eastern Colorado. Journal of Herpetology 13:445-450.

Green, D.M. 1992. Fowler's toads (*Bufo woodhousei fowleri*) at Long Point, Ontario: Changing abundance and implications for conservation. Pages 37-43 *in* C.A. Bishop and K.E. Pettit, editors. Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy. Occasional Paper Number 76, Canadian Wildlife Service.

Hammerson, G.A. 1982. Bullfrog eliminating leopard frog in Colorado? Herpetological Review 13:115-116.

Hammerson, G.A. 1999. Amphibians and Reptiles in Colorado. Second edition. University Press of Colorado and Colorado Division of Wildlife, Niwot, CO.

Hammerson, G.A. 2005. Associate Professor of Biology, Wesleyan University, MA. Personal communication.

Hartman, F.A. 1906. Food habits of Kansas lizards and batrachians. Transactions of the Kansas Academy of Sciences 20:225-229.

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.

Hecnar, S.J. and R.T. M'Closkey. 1997. Changes in the composition of a ranid frog community following bullfrog extinction. American Midland Naturalist 137:145-150.

Hemesath, L.M. 1998. Iowa's frog and toad survey, 1991-1994. Pages 206-216 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Heyer, W.R. 1994. Thread bobbins. Pages 153-155 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Indiana Department of Natural Resources. 2005. Indiana's Endangered Wildlife Classification. Available at http://www.state.in.us/dnr/fishwild/endangered/amphbns.htm.

Hillis, D.M. 1988. Systematics of the *Rana pipiens* complex: Puzzle and paradigm. Annual Review of Ecology and Systematics 19:39-63.

Hillis, D.M., J.S. Frost, and D.A. Wright. 1983. Phylogeny and biogeography of the *Rana pipiens* complex: A biochemical evaluation. Systematic Zoology 32:132-143.

Jaeger, R.G. 1994a. Transect sampling. Pages 103-107 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Jaeger, R.G. 1994b. Patch sampling. Pages 107-109 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Jaeger, R.G. and R.F. Inger. 1994. Quadrat sampling. Pages 97-102 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Jancovich, J.K., E.W. Davidson, J.F. Morado, B.L. Jacobs, and J.P. Collins. 1997. Isolation of a lethal virus from the endangered tiger salamander *Ambystoma tigrinum stebbinsi*. Diseases of Aquatic Organisms 31:161-167.

Jefferies, D.L. and J.M. Klopatek. 1987. Effects of grazing on the vegetation of the blackbrush association. Journal of Range Management 40:390-392.

Johnson, T.R. 1987. The Amphibians and Reptiles of Missouri. Missouri Department of Conservation, Jefferson City, MO.

Johnson, T.R. 1998. Missouri toad and frog calling survey: The first year. Pages 357-359 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Knapp, R.A. and K.R. Matthews. 2000. Nonnative fish introductions and the decline of the mountain yellow-legged frog from within protected areas. Conservation Biology 14:428-438.

Knapp, R.A., K.R. Matthews, and H.K. Preisler. 2003. Developing probabilistic models to predict amphibian site occupancy in a patchy landscape. Ecological Applications 13:1069-1082.

Krebs, C.J. 1999. Ecological Methodology. Second edition. Benjamin Cummings, Menlo Park, CA.

Lamoureux, V.S. and D.M. Madison. 1999. Overwintering habitats of radio-implanted green frogs, *Rana clamitans*. Journal of Herpetology 33:430-435.

Lannoo, M.J. 1998. Amphibian conservation and wetland management in the upper Midwest: A catch-22 for the cricket frog? Pages 330-339 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA. 507 pp.

Lannoo, M., editor. 2005. Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.

Lemen, C., R. Johnson, T. Siebert, D. Ferraro, and J. Lynch. 2003. Reptiles and Amphibians of Nebraska, online reference. Cooperative Extension, University of Nebraska, Lincoln, NE. Available: http://snrs.unl.edu/herpneb/Default.asp.

Lepage, M., R. Courtois, C. Daigle, and S. Matte. 1997. Surveying calling anurans in Québec using volunteers. Pages 128-140 *in* D.M. Green, editor. Amphibians in Decline: Canadian Studies of a Global Problem. Herpetological Conservation Number One. Society for the Study of Amphibians and Reptiles, St. Louis, MO.

Lynch, J.D. 1978. The distribution of leopard frogs (*Rana blairi* and *Rana pipiens*) in Nebraska (Amphibia, Anura, Ranidae). Journal of Herpetology 12:157-162.

Lynch, J.D. 1985. Annotated checklist of the amphibians and reptiles of Nebraska. Transactions of the Nebraska Academy of Sciences 13:33-57.

Madison, D.M. 1997. The emigration of radio-implanted spotted salamanders, *Ambystoma maculatum*. Journal of Herpetology 31:542-552.

Madison, D.M. and L. Farrand. 1997. Habitat use during breeding and emigration in radio-implanted tiger salamanders, *Ambystoma tigrinum*. Copeia 1998:402-410.

Mathews, K.R. and K.L. Pope. 1999. A telemetric study of the movement patterns and habitat use of *Rana muscosa*, the mountain yellow-legged frog, in a high-elevation basin in Kings Canyon National Park, California. Journal of Herpetology 33:615-624.

McLeod, D.S. 2005. Nebraska's declining amphibians. Pages 292-294 *in* M. Lannoo, editor. Amphibian Declines: The Conservation Status of United States Species. University of California Press, Berkeley, CA.

Mecham, J.S., M.J. Littlejohn, R.S. Oldham, L.E. Brown, and J.R. Brown. 1973. A new species of leopard frog (*Rana pipiens* complex) from the plains of the central United States. Occasional Papers of the Museum of Texas Technological University 18:1-11.

Merrell, D.J. 1977. Life history of the leopard frog, *Rana pipiens*, in Minnesota. Bell Museum of Natural History Occasional Papers No. 15:1-23.

Milius, S. 2000. New frog-killing disease may not be so new. Science News 157:133.

Minton, S.A. 1972. Amphibians and Reptiles of Indiana. Indiana Academy of Science, Indianapolis, IN.

Minton, S.A. 1998. Observations on Indiana amphibian populations: A Forty-five-year overview. Pages 217-220 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Morell, V. 1999. Are pathogens felling frogs? Science 284:728-731.

Mossman, M.J., L.M. Hartman, R. Hay, J.R. Sauer, and B.J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pages 169-198 *in* M.J. Lannoo, editor. Status and Conservation of Midwestern Amphibians. University of Iowa Press, Iowa City, IA.

Muths, E., T.L. Johnson, and P.S. Corn. 2001. Experimental repatriation of boreal toad (*Bufo boreas*) eggs, metamorphs, and adults in Rocky Mountain National Park. Southwestern Naturalist 46:106-113.

NatureServe. 2005. NatureServe Explorer: An online encyclopedia of life (web application). Version 4.6. NatureServe, Arlington, VA. Available http://www.natureserve.org/explorer. (Accessed: October 16, 2005).

Newman, R. 1997. Associate Professor, University of North Dakota. Personal communication.

Northern Prairie Wildlife Research Center. 1997. North American Reporting Center for Amphibian Malformations. Jamestown, North Dakota: North Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/narcam (Version 12, April 2001).

Olson, D.H., W.P. Leonard, and R.B. Bury, editors. 1997. Sampling Amphibians in Lentic Habitats. Northwest Fauna No. 4, Olympia, WA.

Pace, A.E. 1974. Systematic and biological studies of the leopard frogs (*Rana pipiens* Complex) of the United States. Miscellaneous Publications of the Museum of Zoology, University of Michigan, No. 148:1-140.

Painter, C. 2000. Endangered Species Biologist. New Mexico Department of Game and Fish. Personal communication.

Parris, M.J. 1998. Terrestrial burrowing ecology of newly metamorphosed frogs (*Rana pipiens* complex). Canadian Journal of Zoology 76:2124-2129.

Parris, M.J. 2001a. Hybridization in leopard frogs (*Rana pipiens* complex): Terrestrial performance of newly metamorphosed hybrid and parental genotypes in field enclosures. Canadian Journal of Zoology 79:1552-1558.

Parris, M.J. 2001b. High larval performance of leopard frog hybrids: Effects of environment-dependent selection. Ecology 82:3001-3009.

Parris, M.J. and R.D. Semlitsch. 1998. Asymmetric competition in larval amphibian communities: Conservation implications for the northern crawfish frog, *Rana areolata circulosa*. Oecologia 116:219-226.

Parris, M.J., R.D. Semlitsch, and R.D. Sage. 1999. Experimental analysis of the evolutionary potential of hybridization in leopard frogs (Anura: Ranidae). Journal of Evolutionary Biology 12:662-671.

Pauli, B.D., J.A. Perrault, and S.L. Money. 2000. RATL: A database of reptile and amphibian toxicology literature. Canadian Wildlife Service, Technical Report Series 357:1-495.

Peterson, C.R. and M.E. Dorcas. 1994. Automated data acquisition. Pages 47-57 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Phillips, C.A., R.A. Brandon, and E.O. Moll. 1999. Field Guide to Amphibians and Reptiles of Illinois. Illinois Natural History Survey, Champaign, IL. Manual 8.

Pilliod, D.S. and C.R. Peterson. 2001. Local and landscape effects of introduced trout on amphibians in historically fishless watersheds. Ecosystems 4:322-333.

Platz, J.E. 1981. Suture zone dynamics: Texas populations of *Rana berlandieri* and *R. blairi*. Copeia 1981:733-734.

Post, D.D. 1972. Species differentiation in the *Rana pipiens* complex. Ph.D. dissertation, Colorado State University, Fort Collins, CO.

Post, D.D. and D. Pettus. 1967. Sympatry of two members of the *Rana pipiens* complex in Colorado. Herpetologica 23:323.

Rand, A.S. and G.E. Drewry. 1994. Acoustic monitoring at fixed sites. Pages 150-153 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Rathbun, G.B. and T.G. Murphey. 1996. Evaluation of a radio-belt for ranid frogs. Herpetological Review 27:187-189.

Reaser, J.K. 2000. Demographic analysis of the Columbia spotted frog (*Rana luteiventris*): Case study in spatiotemporal variation. Canadian Journal of Zoology 78:1158-1167.

Richards, S.J., U. Sinsch, and R.A. Alford. 1994. Radio tracking. Pages 155-158 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Ross, D.A., J.K. Reaser, P. Kleeman, and D.L. Drake. 1999. *Rana luteiventris* mortality and site fidelity. Herpetological Review 30:163.

Scott, N.J., Jr. and R.D. Jennings. 1985. The tadpoles of five species of New Mexican leopard frogs. Occasional Papers of the Museum of Southwestern Biology 3:1-21.

Scott, N.J., Jr. and B.D. Woodward. 1994. Surveys at breeding sites. Pages 118-125 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12:1113-1119.

Semlitsch, R.D. 2000a. Size does matter: The value of small isolated wetlands. National Wetlands Newsletter, January-February 2000:5-13.

Semlitsch, R.D. 2000b. Principles for management of aquatic-breeding amphibians. Journal of Wildlife Management 64:615-631.

Semlitsch, R.D. and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Semlitsch, R.D., J. Pickle, M.J. Parris, and R.D. Sage. 1999. Jumping performance and short-term repeatability of newly metamorphosed hybrid and parental leopard frogs (*Rana sphenocephala* and *Rana blairi*). Canadian Journal of Zoology 77:748-754.

Shirer, H.W. and H.S. Fitch. 1970. Comparison from radiotracking of movements and denning habits of the raccoon, striped skunk, and opossum in northeastern Kansas. Journal of Mammalogy 51:491-503.

Skelly, D.K., E.E. Werner, and S.A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. Ecology 80:2326–2337

Smith, B.E. and D. Keinath. 2005. Species conservation assessment for the northern leopard frog (*Rana pipiens*). In preparation for the USDA. Forest Service.

Smith, G.R., M.A. Waters, and J.E. Rettig. 2000. Consequences of embryonic UV-B exposure for embryos and tadpoles of the plains leopard frog. Conservation Biology 14:1903-1907.

Smith, H.M. 1956. Handbook of Amphibians and Reptiles of Kansas. Second edition. University of Kansas Museum of Natural History, Miscellaneous Publication No. 9, Lawrence, KS.

Stebbins, R.C. 2003. A Field Guide to Western Reptiles and Amphibians. Third edition. Houghton Mifflin Company, New York, NY.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Tyler, J.D. 1991. Vertebrate prey of the loggerhead shrike in Oklahoma. Proceedings of the Oklahoma Academy of Sciences 71:17-20.

U.S. Department of Agriculture. 2003. Threatened, endangered, and sensitive plants and animals. Chapter 2670 *in* FSM 2600-2003-1, Forest Service Manual: wildlife, fish, and sensitive plant habitat management. USDA Forest Service Rocky Mountain Region (Region 2), Denver, CO.

Van Velson, R. 1979. Effects of livestock grazing upon rainbow trout in Otter Creek, Nebraska. Pages 53-55 *in* Proceedings of the Forum – Grazing and Riparian/Stream Ecosystems. O.B. Cope., editor. Trout Unlimited, Denver, CO.

Waye, H.L. 2001. Teflon tubing as radio transmitter belt material for northern leopard frogs (*Rana pipiens*). Herpetological Review 32:88-89.

Welsh, H.H., Jr., and L.M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: A case study from California's redwoods. Ecological Applications 8:1118-1132.

Werner, J.K., J. Weaselhead, and T. Plummer. 1999. The accuracy of estimating eggs in anuran egg masses using weight or volume measurements. Herpetological Review 30:30-31.

Wyman, R.L., ed. 1991. Global Climate Change and Life on Earth. Chapman and Hall, New York, NY.

Zimmerman, B. 1994. Audio strip transects. Pages 92-97 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C.

Appendix A

Plains Leopard Frog (Rana blairi) - Year-round Distribution Model

To give readers of this assessment a brief background regarding the generation of the distribution map in **Figure 3** of the assessment, the following material has been excerpted from:

> Beauvais, G.P. and R. Smith. 2005. Predictive distribution maps for 54 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Report prepared for the U.S. Geological Survey-National Gap Analysis Program by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, WY.

This report details the production of predictive distribution models and maps for 54 species of management concern that occur in the Rocky Mountain Region (Region 2) of the USDA Forest Service. It follows a similar report, completed 30 May 2003, that outlines the development of predictive distribution models and maps for an additional 15 species:

> Beauvais, G.P., R. Thurston, and D. Keinath. 2003. Predictive range maps for 15 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Report prepared for the U.S. Geological Survey-National Gap Analysis Program by the Wyoming Natural Diversity Database-University of Wyoming, Laramie, WY.

Readers are encouraged to consult these reports to fully understand the context of this Appendix. Also, readers are encouraged to consult Beauvais et al. (2004) for a complete discussion of the underlying concepts, procedures, and application of predictive distribution maps in general.

General methods

For most of the target species we used a three part procedure to produce a final predictive distribution map. First, for each species we used points of known occurrence and a region-wide set of climatic variables to model and map a biophysical envelope that efficiently encompassed distributional extent in USDA Forest Service Region 2. Second, we identified the ecological systems (NatureServe 2003) that corresponded to the land cover types identified by each state Gap Analysis team as being associated with each taxon. Finally, to produce final distribution maps, we intersected the biophysical envelope with its associated ecological systems for each target taxon.

Steps 2 and 3 were modified for species known to be associated with riparian environments. For riparian plants, whose distribution is typically better defined by the presence of open water and wetted soils than by dominant vegetation, we did not identify a set of suitable ecological systems with which to intersect the biophysical envelope. Rather, we produced a layer of buffered hydrological features to approximate the extent of riparian environments, and intersected that layer with each taxon's biophysical envelope to produce a final distribution map. For each riparian vertebrate we intersected the biophysical envelope with suitable ecological systems, as described above, but we also added in any buffered hydrologic features not already encompassed by the selected ecological systems. This was equivalent to adding an "unclassified riparian" ecological system to the region-wide ecological systems map, and then including this type in the list of suitable systems for each riparian vertebrate (Merrill et al. 1996).

In general our modeling approach is probably best described as producing 2 individual models for each species, then overlaying the 2 models and identifying their intersection as the best estimate of actual distribution. The first model is inductive; that is, a statistical model of climatic limits as defined by points of known occurrence. The second is a deductive or "expert systems" model of ecological systems (and/or riparian environments) suitable for occupation by the target species. The intersection of the 2 models is assumed to be a better estimate of the distribution of the target species than is either model on its own (see Beauvais et al 2004).

The data manipulations necessary for modeling plains leopard frog (*Rana blairi*) are discussed below; most notably, preparation of occurrence data and post-processing of the general modeling procedure.

Occurrence data for each target taxon were collected from a variety of sources and required several filtering steps to produce a subset that could be used to estimate a relatively unbiased biophysical envelope for each species (Beauvais et al. 2004). Filtering was done using the ArcInfo and ArcView (Environmental Systems Research Institute, Redlands, California) geographic information systems.

Occurrence data filtering

Originally 2878 records of occurrence in three states (CO, NE, KS). All filters below resulted in 326 remaining records in three states (CO, NE, KS). This dataset was then separated into 240 modeling points and 86 validation points.

Identity filter

We removed all records with "questionable", "unlikely", or similar explicit entries in any species-identification field in the contributed datasets. We also removed all records for which there was no explicit entry in a species-identification field, with the exception of datasets that consistently did not include this information.

Map precision filter

We removed all records with "unmappable" precisions, as explicitly noted in mapping precision fields within the contributed datasets. We also removed all records denoted as having mapping precisions of ca. +5 miles or greater (e.g., "G" precision points from state Natural Heritage Program datasets). The Sternberg Museum of Natural History provided many records of unknown spatial resolution; these records accounted for all records available for Kansas. Removal of these records would have not only substantially reduced the overall sample size of observation points, but would also have resulted in a geographic bias away from Kansas. Therefore, these records were retained despite their unknown spatial precision.

Date-of-observation filter

We removed all records recorded prior to 1970, based on the general assumption that the range of the taxon has not changed substantially over the past 35 years. We also removed all records where the date of observation was not given (i.e., the database field was blank) in the contributed dataset.

Seasonal filter

There was no seasonal filter for this species.

Spatial filter

We removed records such that no 2 points were within 1,600 m of each other.

Additional biogeographic filter

Current information suggests a rather broad zone of overlap between the plains leopard frog and the similar northern leopard frog (*Rana pipiens*), in eastern and central Nebraska. Whereas the latter species is thought to occur only north of ca. 41 degrees latitude in Nebraska, the former occupies the entire southern half of the state and sweeps north into southeastern South Dakota through eastern Nebraska. See:

> Stebbins, R.C. 2003. Western reptiles and amphibians. Third edition. Houghton Mifflin, New York, NY.

Our original dataset of points of known occurrence of plains leopard frogs includes records in northern and western Nebraska where the species is thought to be absent; it is likely that this includes a substantial number of observations. To avoid skewing our models and resulting maps, we took the conservative approach of eliminating all supposed plains leopard frog points in Nebraska north of 41 degrees latitude from our modeling and validation datasets.

Biophysical envelope modeling

Variable 1

Elevation: A general biophysical parameter that integrates many aspects of climate, especially temperature and precipitation. Elevation varies strongly across the study area, with substantial gradients evident in even the relatively flat eastern 2/3.

Variable 2

Mean annual precipitation: A general biophysical parameter indicating the overall wetness of an area. Mean annual precipitation varies strongly across the study area along a general low - high (dry - wet) axis in mountainous areas and a general west - east (dry - wet) axis in the plains. A principal components analysis of 30 variables identified this as 1 of 4 relatively independent variables that explain the most climatic variation in the study area.

Variable 3

Mean number of frost days per year: A general biophysical parameter indicating the mildness/ harshness of the climate. Mean number of frost days per year varies strongly across the study area along a general low - high (few - many) axis in mountainous areas and a general west - east (many - few) axis in the plains. A principal components analysis of 30 variables identified this as 1 of 4 relatively independent variables that explain the most climatic variation in the study area.

Variable 4

CV of monthly precipitation: A general biophysical parameter indicating the consistency or "reliability" of precipitation. A principal components analysis of 30 variables identified this as 1 of 4 relatively independent variables that explain the most climatic variation in the study area.

Variable 5

Radiation of the darkest month: A general biophysical parameter indicating solar input in winter. Radiation of the darkest month varies strongly across the study area along a north (darker) to south (lighter) axis. This contrasts with most other predictor variables which grade the study area in a west-east fashion, and thus is an important variable to consider when constraining species' distributions. A principal components analysis of 30 variables identified this as 1 of 4 relatively independent variables that explain the most climatic variation in the study area.

Associated ecological systems and riparian environments

- ❖ North American Arid West Emergent Marsh (25)
- ❖ Eastern Great Plains Wet Meadow Prairie and Marsh (26)
- ❖ North Central Interior Floodplain/Wooded Draw (28)
- ❖ Open Water (35)
- ❖ Rocky Mountain Lower Montane Riparian Woodland and Shrubland (48)
- ❖ Western Great Plains Closed Depression (61)
- ❖ Western Great Plains Riparian/Western Great Plains Floodplain (64)
- ❖ Western Great Plains Saline Depression (65)

The following ecological systems were identified as suitable based on the straight cross-walk from Gap Analysis land cover types; they were removed from the list based on unsuitability as habitat.

- ❖ Rocky Mountain Foothill Grassland
- ❖ Western Great Plains Sand Prairie
- ❖ Central Mixed-grass Prairie
- ❖ Southern Rocky Mountain Montane Grassland
- ❖ Western Great Plains Shortgrass Prairie
- ❖ Rocky Mountain Juniper Woodland and Savanna
- ❖ Southern Rocky Mountain Pinyon - Juniper Woodland

Riparian environments were approximated across the study area by buffering all hydrographic features in the National Hydrography Dataset by 50 meters. Buffered riparian areas not already encompassed by the above ecological systems were also included in the final distribution model.

Results and evaluation

The biophysical envelope encompassed 95 percent of the points of known occurrence in the modeling dataset, and 92 percent of the points of known occurrence in the independent validation set.

The intersection of the biophysical envelope and associated ecological systems (including additional unclassified riparian areas) encompassed 25 percent of the points of known occurrence in the modeling dataset, and 29 percent of the points of known occurrence in the independent validation set.

The low classification success of the latter model is likely due, at least in part, to the low mapping precision of many of the points of known occurrence in combination with the narrow and linear nature of many of the suitable ecological systems. As discussed above ("map precision filter") it was necessary to retain many coarsely-mapped points in order to maintain an adequate sample size and distribution. Because the plains leopard frog is largely restricted to wetland and riparian environments, and because the ecological systems that represent those environments typically occur as narrow strips, it is unlikely that coarsely-mapped observation points will plot exactly within those system types.

Also, the narrow and linear nature of riparian land cover types and ecological systems makes them very difficult to map, and thus many small riparian corridors and patches are not shown in the ecological systems map used in this project. This deficiency in the land cover map is another reason for the relatively low validation success of our final model - i.e., some points of known occurrence map onto small wetlands that do not appear on the environmental layers used in this project, and thus those points are classified as "misses" by our modeling and validation procedures. It should be recognized that our final model underpredicts potentially occupied range at fine geographic scales. Although this does not affect the model's ability to show distribution across the region and individual states, it does limit its application to individual national forests, national grasslands, and ranger districts. Because more precise layers of riparian land cover often exist for these management units, we recommend that such layers be used in conjunction with our biophysical model to inform discussions of this taxon's distribution at fine scales.

Our models do not predict suitable environments for the plains leopard frog in southeastern Colorado, an area clearly occupied by the taxon. This is likely due to this area being on the extreme fringe of environmental suitability for the taxon, and our modeling technique that defines suitable environments as those that encompass 95 percent of the points of known occurrence in the modeling dataset. Said differently, if one considers the multivariate frequency distribution of environmental values defined by all modeling points in this area, the points of known occurrence in southeastern Colorado fall in the 5 percent "tail" at one extreme of that distribution.

Appendix B

Design and Implementation of Inventory and Monitoring Plans for Local, State, and Federal Agencies

by

Brian E. Smith
Department of Biology,
Black Hills State University,
1200 University Street Unit 9044,
Spearfish, SD 57799-9044

Standard references that discuss planning an inventory, inventory techniques, monitoring protocols, data management, and data analysis for herpetofauna are Heyer et al. (1994), Olson et al. (1997), and Lips et al. (2001). Developing a monitoring protocol can be a complicated process requiring the services of specialists in statistics, sampling theory, and herpetofauna. However, in my experience in inventory and survey of northern leopard frogs for federal, state, and local agencies in North Dakota, South Dakota, Wyoming, and Nebraska, inventory and monitoring for land managers should not and need not be that complicated. Land managers typically have a very heavy workload and funding and personnel are usually in short supply. However, it is important to monitor amphibians both because of the concern for amphibian declines within the United States (Lannoo 2005) and because it may be required as part of a land manager's workload. I tentatively propose the following basic inventory and monitoring guidelines for the northern Great Plains region based on my experience with land managers, but I realize that these ideas have not been subjected to rigorous testing. I would point out that more research is needed in the practical application of simple inventory and monitoring methods designed for the typically overworked land manager and his or her staff. I strongly suggest that managers starting an inventory and monitoring program consult with a professional herpetologist prior to initiating such a project.

1) <u>Sampling Design</u>: Arguments about sampling design and theory are legion at professional herpetological meetings (Smith personal experience). Professional statisticians often disagree about the best sampling design and there is by no means a consensus in the herpetological community. One approach would be to hire a statistician specializing in sampling theory to devise a sampling strategy. This would be the best method to develop a sophisticated monitoring strategy, but sampling methods change on a routine basis and many agency biologists become frustrated at being told that their sampling design is out of date every few years.

I believe that what an agency biologist probably wants to know is whether anurans are declining in his or her jurisdictional area and the types of habitat used by anurans. One approach would be to consult with a professional herpetologist who can suggest appropriate habitat to monitor and who can spend some time in the field visiting wetlands with agency biologists. I suggest that agencies monitor only sites that were known to have populations of frogs at the start of the monitoring effort. Although it is of interest to know the number of occupied versus unoccupied breeding sites in an inventory effort, I feel that trends in abundance would most easily and efficiently be tracked by starting the monitoring program with several sites that have frogs. If frogs go extinct at one of these sites during the monitoring period the site should continue to be monitored for potential recolonization.

It is not necessarily clear what types of water bodies will be occupied by anurans. I have found anurans in very temporary ponds such as roadside drainage ditches, degraded wetlands, relatively pristine small ponds with emergent vegetation, ponds that fill in spring and dry by the end of summer, and at lake margins in emergent vegetation. If funding is sufficient, a season of work by a trained herpetological crew would be of great help to find suitable monitoring sites. At the very least, a professional herpetologist should be consulted at this stage.

By identifying sites where northern leopard frogs occur, agencies can monitor these sites for signs of decline through time. More sophisticated studies, or simple experience over time if funding is lacking, might help agency biologists create new habitat or conserve appropriate habitat for the species.

2a) <u>Basic Technique 1</u>: Techniques used to start a monitoring program can be very simple. Sometimes auditory surveys can be used, but this may require a trained ear for some calls (such as northern leopard frogs), although certain frogs are easily heard (such as boreal chorus frogs). Many workers conduct auditory surveys for three minutes at each site, and this is appropriate for frogs of the northern Great Plains that have loud and obvious calls. Before this point, managers need to learn some basics of the natural history of targeted species, either from the literature (standard field guides can be used) or from a seasoned field worker or professional herpetologist, to determine whether field personnel can easily and accurately record calling anurans. If auditory surveys are used I suggest sending trained observers to several breeding ponds a night during the spring breeding season (typically April to July in the northern Great Plains, depending on elevation and weather), listening for about three minutes at each site. Most species of the northern Great Plains begin calling after sundown and may call all night. If a breeding chorus is confirmed the site does not necessarily need to be visited again that breeding season. However, lack of calling does not necessarily indicate the absence of frogs. Observers should visit each site at least three times during the breeding season before concluding that there are no frogs at the site during a given breeding season. Auditory surveys cannot be used to determine successful reproduction. All that can be determined is that a breeding chorus was found at specific sites during the breeding season.

2b) Basic Technique 2: In my experience, certain anurans, like northern leopard frogs, are more easily detected later in the active season (June – October, depending on weather and elevation), when subadults and adults may be found at the edges of wetlands basking in the sun. They are then easily observed with simple visual searches. Once again, it is important to know some natural history of the species before initiating an inventory and monitoring effort. A seasoned field worker or professional herpetologist should be consulted at this stage. Once again, a single observation at a site is sufficient to score presence of the species at the site, and sites must be visited at least three times for frogs to be considered absent at the site. Visual surveys can be timed (Crump and Scott 1994) and observations turned into encounter rates that can then be used in simple statistical analyses of abundance through time. In my studies, I have typically used two person-hour searches (e.g., four investigators working for 30 minutes, three for 40 minutes, or two for one hour), except at very small ponds that can be completely searched in less time, to standardize the sampling protocol. This technique can be used to indicate successful reproduction at a site (if subadults or larvae are confirmed at a site).

3) Sampling of Tadpoles: Tadpoles can be sampled in various ways, including dipnets and various aquatic traps, but I usually discourage the use of this technique for routine survey work by non-herpetologists for several reasons. Sometimes it is difficult to collect tadpoles using dipnets in thick vegetation at the edges of ponds. In addition, tadpoles are difficult to identify, even by trained individuals, and it is likely that misidentifications will compromise the data. Third, when using dipnets to sample tadpoles, diseases could easily be transferred from pond to pond if dipnets are not properly disinfected (see item 6 below).

4) Geographical Information Systems: All data should be entered into the GIS database for each jurisdictional area to track locality data more closely. Various authors (Hayek and McDiarmid 1994, Juterbock et al. 1994, Fellers 1997) discuss the use of GIS in herpetofaunal studies, but GIS is a universal system used for many applications. Many agencies have GIS experts that can assist in compiling data into a format that can easily be traded amongst researchers and used by managers.

5) Number of Sampling Sites: There is no consensus on the number of sites that should be monitored across a region to examine trends in abundance and there is no standard used amongst studies, herpetological or otherwise. However, Hayek and Buzas (1997) determined from theoretical considerations that a sample size of 20 should be adequate to infer biologically meaningful results from most biological data sets. I tentatively suggest that a minimum of 20 ponds should be monitored on a management unit, but I should also note that any statistical textbook (e.g., Sokal and Rohlf 1994, Zar 1998) will point out that sample sizes should be as high as is reasonable. I am fully aware of the fact that many factors will influence the number of ponds to be monitored, including size of the management area, number of suitable wetlands, funding, personnel, and possibly

other factors. Somewhat reassuringly, Hayek and Buzas (1997) also found that sample sizes of less than 20 might be adequate in some cases. However, I strongly recommend that at least 20 ponds be monitored for a meaningful monitoring effort. If fewer ponds are found within a management unit, a professional herpetologist should be consulted. However, Hayek and Buzas (1997) have suggested that sample sizes as small as 5 can be used to track trends in some cases.

6) Disinfection of Sampling Gear: Preferred techniques, such as acoustic monitoring and some types of visual surveys, do not require entry into ponds or may require minimal work in wet pondsides. If workers are in and out of water to any extent, rubber boots should be worn and sprayed with a 10 percent bleach solution between survey ponds to disinfect the boots. Any equipment used should be similarly disinfected. This should reduce the chance of transmission of disease from pond to pond. The gear must then be rinsed with distilled water before the next visual survey, since bleach is also harmful to amphibians.

7) Historic Surveys: It is very instructive to compare historical data to current data. The historic survey uses locality data from sources such as museum collections, natural heritage databases, or observational databases that some agencies and land managers maintain. These localities are revisited to determine presence or absence of the target species and examine general trends in distribution. Although the resulting presence/absence data lack statistical precision, the results are illustrative nonetheless. Declines are often inferred from distributional data. The advantages and disadvantages of historic surveys are discussed by Fellers (1997).

Olson et al. (1997) provided a number of very readable papers on inventories, surveys, and monitoring that should be consulted by managers interested in instituting an inventory and monitoring program.

References

Crump, M.L. and N.J. Scott, Jr. 1994. Visual encounter surveys. Pages 84-92 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayak, and M. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C. 364 pp.

Fellers, G.M. 1997. Design of amphibian surveys. Pages 23-34 *in* D.H. Olson, W.P. Leonard, and R.B. Bury, editors. Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Northwest Fauna Number 4. Society for Northwestern Vertebrate Biology, Olympia, Washington. 134 pp.

Hayek, L.-A.C. and M.A. Buzas. 1997. Surveying Natural Populations. Columbia University Press, New York, NY.

Hayek, L.-A.C. and R.W. McDiarmid. 1994. GIS and remote sensing techniques. Pages 166-171 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayak, and M. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C. 364 pp.

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C. 364 pp.

Juterbock, J.E., S.S. Sweet, and R.W. McDiarmid. 1994. Manual GIS application for habitat specialists. Pages 171-175 *in* W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayak, and M. Foster, editors. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, D.C. 364 pp.

Lips, K.R., J.K. Reaser, B.E. Young, and R. Ibáñez. 2001. Amphibian Monitoring in Latin America: A Protocol Manual. Society for the Study of Amphibians and Reptiles Herpetological Circular Number 30:1-115.

Olson, D.H., W.P. Leonard, and R.B. Bury, editors. 1997. Sampling Amphibians in Lentic Habitats: Methods and Approaches for the Pacific Northwest. Northwest Fauna Number 4. Society for Northwestern Vertebrate Biology, Olympia, WA.

Sokal, R.R. and F.J. Rohlf. 1994. Biometry. Third edition,.W.H. Freeman, New York, NY.

Zar, J.H. 1998. Biostatistical Analysis. Fourth edition. Prentice Hall, Upper Saddle River, NJ.