

Boreal Toad (*Bufo boreas boreas*) A Technical Conservation Assessment



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

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COVER PHOTO CREDIT

Boreal Toad (*Bufo boreas boreas*). Illustration by Summers Scholl. Used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE BOREAL TOAD

The boreal toad (*Bufo boreas boreas*) shows declines in population size and distribution across its range in western North America. The population in the Southern Rocky Mountains (Wyoming, Colorado, and New Mexico) is particularly vulnerable to extinction during declines as it is geographically isolated from all other populations of boreal toads.

Scientists believe the chytrid fungus *Batrachochytrium dendrobatidis* to be a contributing factor in boreal toad declines since the 1970s and currently see it as the primary threat to boreal toad populations throughout the Southern Rocky Mountains. However, the impact of *B. dendrobatidis* is compounded by other threats, the most widespread being habitat alteration from human disturbances around wetlands and human-facilitated expansion of natural and introduced predators. Habitat fragmentation further isolates breeding populations, which increases the effects of these widespread threats and the risk associated with other threats, such as local changes in water quality, timber harvest, livestock grazing, fire, and toxic chemicals (e.g., pesticides and herbicides).

The main conservation concerns for land managers should be managing disease, cataloging and monitoring population status, delineating important habitat, and protecting delineated habitat. Of specific importance are developing techniques to effectively detect and treat *Batrachochytrium dendrobatidis* infections in both wild and captive populations of boreal toads and identifying and protecting current breeding sites from habitat degradation, especially in the Southern Rocky Mountains. In order to ensure the survival of boreal toads in Region 2, local management plans must assess the impact of the threats discussed in this document at both the scale of the landscape connecting boreal toad populations and within individual populations. Further, it is necessary for land managers to preserve critical wetland and terrestrial habitats not only by directly protecting these areas but also by identifying important processes that create and maintain these habitats and working to ensure that these processes are functioning properly.

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INTRODUCTION

Goal

This conservation assessment of the boreal toad (*Bufo boreas boreas*) was prepared in support of the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) (**Figure 1**). It addresses the biology, ecology, conservation, and factors and considerations paramount in conserving and managing the boreal toad throughout its current range in Region 2. Our goal is to provide a current summary of published information and expert interpretation of this information that biologists can use to develop management plans and conservation strategies.

The boreal toad was selected for a conservation assessment because USFS Region 2 classifies it as a sensitive species and because it is a candidate for listing under the Endangered Species Act. Both

of these designations are due to recently observed declines in abundance and distribution across its range, and particularly in the Southern Rocky Mountains. The boreal toad was once widespread and common throughout its range, but it has declined dramatically over the past 20 years (Loeffler 2001).

Scope

The boreal toad conservation assessment examines the biology, ecology, conservation, and management of this species throughout its range and with specific reference to the geographic and ecological characteristics of Region 2. This assessment depends on some boreal toad studies conducted outside the region, but that information is considered in the context of the ecological setting of the central and southern Rocky Mountains. This assessment will focus on the characteristics of boreal toads in the context of current environmental conditions with comparisons made between current and historical status.

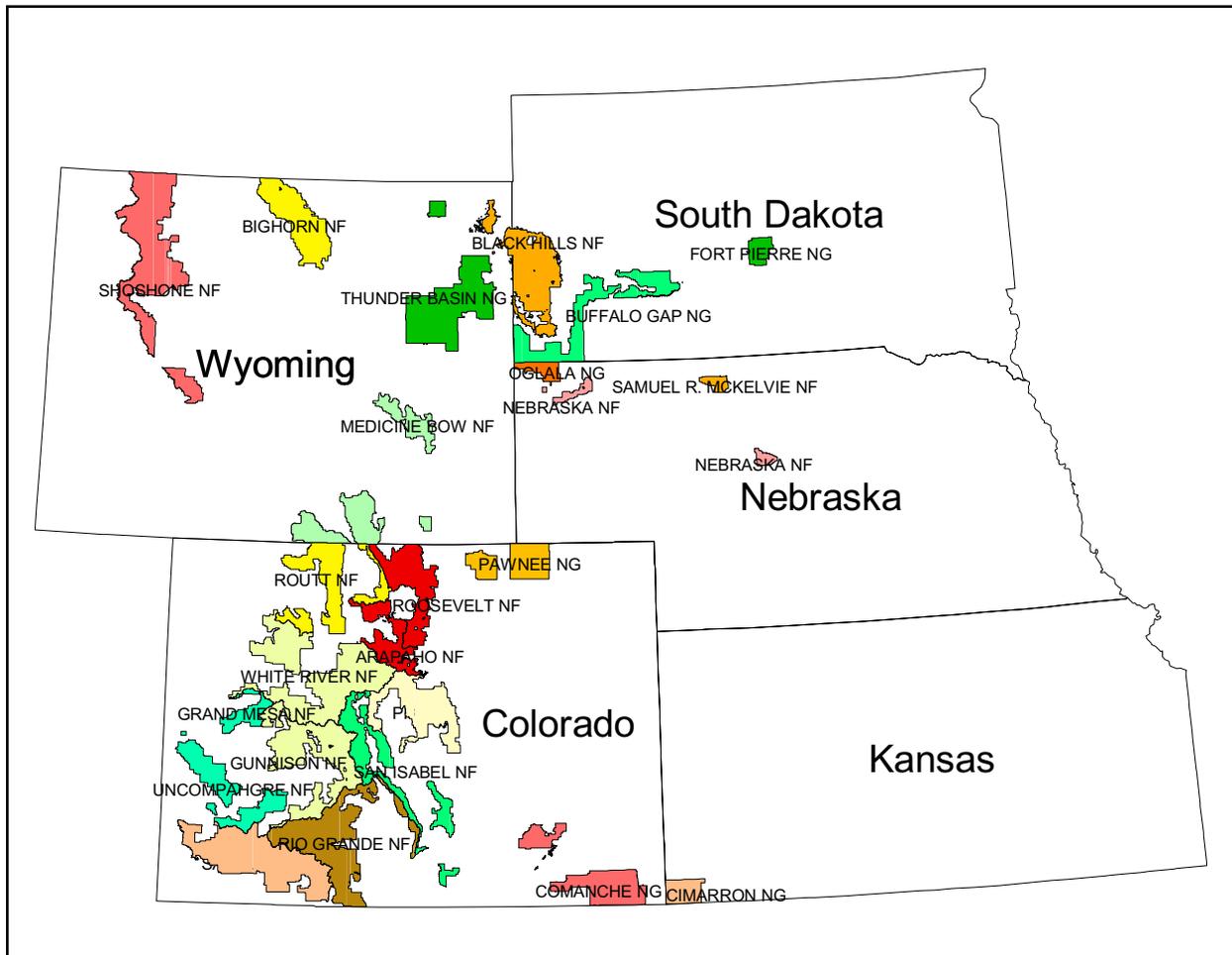


Figure 1. Map of USDA Forest Service Region 2 national forests and grasslands.

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

This assessment is based on the best information currently available and does not include new research from the authors, other than a synthesis of this information to develop sensitivity/elasticity estimates.

Uncertainty and Limitations

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 opinions from several sources when there is little or no research to back up specific hypotheses. Limitations on the content and quality of information in this assessment include the limited data on boreal toad occurrences in some parts of Region 2 and the work-in-progress nature of our understanding of boreal toads in the Rocky Mountains.

Peer Review and Treatment of Web Publications

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the World Wide 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 in order to facilitate its use by USFS personnel, other agencies

and organizations, and the public. This will make information on the boreal toad accessible more rapidly than publication as a report. Web publication will also make revisions more efficient and timely. A link to this publication will also be available on the Wyoming National Diversity Database web site.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal Endangered Species Act

The Southern Rocky Mountain Population (SRMP) of boreal toads was originally petitioned for listing under the U.S. Endangered Species Act in September 1993. It was designated a candidate for Federal listing as a result of a positive 12-month finding published in 1995 (U.S. Fish and Wildlife Service 1995) and in subsequent reviews (U.S. Fish and Wildlife Service 2002, 2004). The U.S. Fish and Wildlife Service (USFWS) found the boreal toad to be warranted for listing, but it is currently precluded from listing by a backlog of species listing actions of higher priority. The most recent review (U.S. Fish and Wildlife Service 2004) stated:

Despite numerous conservation actions funded and implemented to date, additional populations or breeding localities of the toad being found in the last several years, and protection of the toad afforded by State and Federal laws, we continue to give the toad a listing priority of 3. The chytrid fungus infection is an ongoing threat of high magnitude and is likely to extirpate additional infected boreal toad populations. [Where "3" indicates they are a candidate for listing as threatened.]

Through a legal settlement in October 2002, the UWFWS agreed to decide whether to list the SRMP of boreal toads by September 2005.

Bureau of Land Management

The boreal toad is currently on the Bureau of Land Management (BLM) sensitive species list in Wyoming (Bureau of Land Management Wyoming 2001), but not in any other Region 2 states.

USDA Forest Service

Region 1 and Region 2 of the USFS both classify the boreal toad as a sensitive species (USDA Forest Service 1999, USDA Forest Service 2003).

State wildlife agencies

The Wyoming Game and Fish Department ranks the boreal toad as a native species of special concern 1 (NSS1) (Oakleaf et al. 2002, B. Turner personal communication 2004). The Colorado Division of Wildlife ranked the SRMP of the boreal toad as endangered in 1993 (Colorado Rev. Stat. Ann. §§33-2-109 et seq) (Colorado Division of Wildlife 2000), and it has been ranked as endangered in New Mexico since 1976 (New Mexico Stat. Ann. §§17-2-37 et seq) (New Mexico Game and Fish Department 1988). The boreal toad is not present in South Dakota, Nebraska, or Kansas.

Natural Heritage Program

The Natural Heritage Program gives taxonomic groups ranks at the global level (G-ranks) and state level (S-ranks). Those population segments with special taxonomic considerations (e.g., distinct population segments, like that of the Southern Rocky Mountain boreal toad) are also given tertiary ranks (T-ranks). Each rank follows a numerical scoring system defined as follows (NatureServe Explorer 2002, Keinath and Beauvais 2003, Keinath et al. 2003):

- 1 = Critically Imperiled: At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
- 2 = Imperiled: At high risk of extinction due to restricted range, few populations (often 20 or fewer), steep declines, or other factors.
- 3 = Vulnerable: At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors. Such species are often rare or found locally in a restricted range.
- 4 = Apparently Secure: Uncommon but not rare; some cause for long-term concern due to declines or other factors. Such species are likely to be quite rare in parts of their range, especially at the periphery.

5 = Secure: Common; widespread and abundant. Such species are potentially rare in parts of their range, especially at the periphery.

Q = Questionable Taxonomy: Taxonomic distinctiveness of this entity at the current level is questionable (e.g., G2Q); resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or the inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority conservation priority.

In Wyoming, the Northern Rocky Mountain Population (NRMP) of boreal toads is ranked as G4T4/S2 while the SRMP is ranked as G4T1Q/S1 (Keinath and Beauvais 2003, Keinath et al. 2003, NatureServe 2005). In Colorado, the boreal toad is ranked as G4T1Q/S1 (Colorado Natural Heritage Program 1999, NatureServe 2005). In New Mexico, the boreal toad is ranked as historically present and possibly extirpated (SH) (New Mexico Natural Heritage Program 2002, NatureServe 2005). In Alberta, Canada the boreal toad (NRMP) is listed as S4 (NatureServe 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Existing regulatory mechanisms

Boreal toads are protected as endangered species in Colorado (Colorado Rev. Stat. Ann. §§33-2-109 et seq) and New Mexico (New Mexico Stat. Ann. §§17-2-37 et seq). In Colorado, this designation provides a basic mandate for the Colorado Division of Wildlife to conserve the boreal toad and prohibits the collection, possession, or sale of this species. However, it does not include measures to protect boreal toad habitat. The Wyoming Game and Fish Commission regulation (Chapter 52, Section 11) classifies boreal toads as Native Species Status 1 (NSS1), which means that the species is rare and declining and that the habitat for this species is declining; but this status carries no legal, regulatory, or management weight.

Because the boreal toad remains a candidate for federal listing, it currently has no legal status under federal law. Lack of federal oversight and protection may limit coordinated efforts to stem and reverse the observed declines of this species in Region 2.

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. Except perhaps at a few localities, there has been no discernable positive impact on population trends for boreal toads in Region 2 that can be directly attributable to management actions, so these mechanisms appear inadequate to conserve boreal toad populations in the Rocky Mountains.

Existing management plans

Southern Rocky Mountain Population

The multi-agency Boreal Toad Recovery Team (BTRT) was formed in 1994 to provide coordinated recommendations on the conservation and management of the SRMP of boreal toads. The team consists of a core group made up of representatives from all agencies that have a legal responsibility and authority to implement management actions, and a Technical Advisory Group made up of persons who have expertise regarding boreal toads, their habitat, or other specific knowledge vital to the implementation of recovery and conservation efforts. The agencies represented on the BTRT include the Colorado Division of Wildlife, New Mexico Game and Fish Department, Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, U.S. Geological Survey/Biological Resources Division, USDA Forest Service, National Park Service, Bureau of Land Management, and Environmental Protection Agency.

The BTRT has the primary responsibility for the development and implementation of a recovery/conservation plan for the SRMP. Such a plan was finalized in 1994 (Nesler and Goettl 1994), and a conservation plan followed in 1998 (Boreal Toad Recovery Team 1998), with updates in February 2001 (Loeffler 2001). This recovery team is composed of personnel with the authority, expertise, and commitment needed to take on the challenges associated with the recovery of this species, and it is the authors' opinion that the Conservation Plan and Agreement developed by the BTRT is a valuable reference for any person in a position to conduct management actions for the conservation of this species.

The revised conservation plan (Loeffler 2001) lists the following management objectives:

- ❖ prevent the extirpation of boreal toads from the area of their historic occurrence in the

Southern Rocky Mountains, which includes eleven mountain ranges, or geographic areas, covering southern Wyoming, northern New Mexico, and much of Colorado

- ❖ avoid the need for federal listing of the boreal toad under the Endangered Species Act
- ❖ recover the species to a population and security level that will allow it to be de-listed from its present endangered status in Colorado and New Mexico.

Detailed descriptions of down-listing and de-listing requirements (within Colorado) and population viability are provided in the conservation plan (Loeffler 2001). In general, for a population to be considered viable, a specified minimum number of toads must successfully breed for a set number of years (i.e., there must be significant recruitment), and external threats to the habitat, health, or environmental conditions of the population must be eliminated. Down-listing and/or de-listing will be considered when a specified number of viable populations over an adequate geographic area are confirmed. Currently, there are few areas within the SRMP that meet established viability standards (Loeffler 2001). Boreal toad populations in the Sawatch Range, mostly within Chaffee County, Colorado, have met the above standards, but a majority of the known populations in the Southern Rocky Mountains do not have this level of recruitment, and many show dramatic declines.

Northern Rocky Mountain Population

Thus far, no coordinated conservation efforts have been made with respect to the NRMP of boreal toads in Region 2. There have been reviews of boreal toad status prepared for specific regions of the Northern Rocky Mountains (e.g., Patla (2001) for the Bridger-Teton National Forest and Maxell (2000) for Montana). However, neither of these documents represents nor has been used to develop a coordinated management plan. Much of the conceptual and biological information generated for the SRMP loosely applies to the NRMP.

Existing conservation strategies

The following steps outline the main conservation strategy recommended by the BTRT (Loeffler 2001):

- ❖ identify and inventory potential boreal toad habitat throughout its historic range

- ❖ monitor breeding populations identified via inventories, with the goal of obtaining reliable population trend data
- ❖ identify and investigate known and potential threats to boreal toads and their habitat
- ❖ establish recovery goals based on population viability estimates that incorporate genetic factors
- ❖ protect and manage critical populations with respect to known threats
- ❖ pursue opportunities to expand the size and number of breeding populations including transplantation and captive reintroduction
- ❖ conduct a public education campaign concurrent to the above recovery efforts.

This conservation strategy, accepted by a team of experts in amphibian research and management, should be considered as the best available for the conservation of boreal toads.

Biology and Ecology

Description

Adult boreal toads vary in coloration from dark brown or black to olive with a distinct white or pale yellow mid-dorsal stripe (**Figure 2**). This stripe is most evident in mature females, but it is not always visible, especially if the toad is cold (L.J. Livo personal communication 2002). The throat is pale, relative to the rest of the body, and the sides and belly are covered with many dark spots, but no yellow spots. The skin is typically dry and warty. A large, oval, glandular lump (parotid gland) is present behind each eye. Boreal toads lack distinct bony ridges around the eyes (i.e., cranial crests). Males develop thickened, dark areas on the inner surfaces of their innermost front toes (“thumbs”) during the breeding season; these pads may become less distinct after the breeding season. These nuptial pads help the male grip the female during amplexus. Adult females range from 3 to 4 inches (75 to 100 mm) in length from snout to vent while adult males are generally smaller, ranging from 2.4 to 3.2 inches (60 to 80 mm) in length. Boreal toads have no vocal sacs. During the breeding season, adult males make soft chirping sounds, a recording of which can be found on the Colorado Herpetofaunal Atlas Web site (<http://ndis.nrel.colostate.edu/herpatlas/coherpatlas/>).

An immature boreal toad (metamorph) differs from an adult in that it may lack a distinct dorsal stripe; it has yellow or orange spots on the ventral surfaces of its feet; and it may have orange to red spots on its body (**Figure 3**). Metamorphs may also have yellow foot tubercles.

The boreal toad differs from spadefoot toads (*Spea* spp.) by the presence of swollen parotid glands (noted above), horizontal rather than vertical pupils, and the absence of a sharp cutting edge (tubercle) on each hind foot. In the adult phase, they differ from Woodhouse’s toad (*Bufo woodhousii*) by the absence of conspicuous cranial crests between and behind the eyes; however, the eggs and larvae of boreal toads and Woodhouse’s toads are very similar (Baxter and Stone 1985, Stebbins 1985, Hammerson 1999).

Eggs of boreal toads are black above and white below, or completely black. The ovum average 1.5 to 1.8 mm in diameter, but they are encased in two jelly layers that make them appear to be approximately 5 mm in diameter (Livezy and Wright 1947, L.J. Livo personal communication 2002). Healthy females have two functional oviducts, so eggs normally occur in two strands that often appear to be a single zigzag row. Encased in their gelatinous sheaths, eggs typically are deposited in shallow water (**Figure 4**; Samollow 1980, Olson 1989, Koch and Peterson 1995, Hammerson 1999). They may become tangled in vegetation or covered by silt and debris. The number of eggs per clutch varies widely across the range of boreal toads in North America and is loosely correlated with body size (Stebbins and Cohen 1994). In Colorado, clutch sizes from three different populations ranged from 3,200 to over 10,800 eggs per clutch, with clutch size decreasing insignificantly from south to north (Livo 1999).

Boreal toad tadpoles are typically black or dark brown in color, including the fins (**Figure 5**). They range in size from 6 mm when they hatch to 34 to 37 mm (1.3 to 1.5 inches) when they are fully developed. Their eyes are not on the sides of the head as in some amphibian species (e.g., Western chorus frog [*Pseudacris triseriata*]); instead, they are positioned about halfway between the midline and the lateral edge of the head (Nussbaum et al. 1983, Baxter and Stone 1985, Stebbins 1985, Koch and Peterson 1995, Corkran and Thoms 1996, Hammerson 1999).

Systematics

The currently accepted scientific name for the western toad is *Bufo boreas*. There are currently three

(A)



(B)



Figure 2. Adult boreal toads from the (A) Northern Rocky Mountain Population (Photo by Deb Patla) and (B) Southern Rocky Mountain Population (Photo by Chuck Loeffler).



Figure 3. Metamorph boreal toad (Photo by Deb Patla).



Figure 4. Eggs of the boreal toad (Photo by Deb Patla).



Figure 5. Tadpoles of the boreal toad (Photo by Deb Patla).

nominal subspecies in the *B. boreas* complex: *B. b. boreas* (boreal toad), *B. b. halophilus* (California toad or alkali toad), and *B. b. nelsoni* (Amargosa toad) (Stebbins 1985, Collins 1990, Crother et al. 2001). There is moderate confidence in the subspecies designations based on geographic separation and genetic differences. However, some recent genetic analyses suggest that these groups are, in fact, separate species (Goebel 1996). There are at least four phylogenetic groups of western toads that may eventually be recognized as separate species (Goebel 1996). The SRMP of boreal toads (southern Wyoming, Colorado, and New Mexico) is geographically isolated from the NRMP (northern Wyoming, Idaho, and Montana) by dry, non-forested intermountain valleys. These populations have proven to be genetically differentiated and probably represent independently evolving lineages or species (Goebel 1996). There is evidence that boreal toads in northern Utah and Sublette County, Wyoming may be of the same lineage as those in the SRMP, but additional data are needed to confirm that hypothesis. The southern Utah group and the southwestern group (southern Nevada, southern California) are also recognized as geographically isolated and genetically distinct populations (Goebel 1996).

Range, distribution, and distribution trends

The range of the boreal toad currently extends from southern Alaska through British Columbia, Washington,

Oregon, and northern California and east through Idaho, western Montana, western and south-central Wyoming, Nevada, the mountains and higher plateaus of Utah, and portions of the mountains of Colorado (**Figure 6**). It has not been recorded at low elevations (<6,000 ft.) east of western Wyoming (Baxter and Stone 1985), western Montana, and central Colorado (Stebbins 1985). New Mexico populations are now thought to be extinct (Degenhardt et al. 1996, NatureServe 2005). Boreal toads have also been reported from the Yukon and Alberta (Cook 1977, Wind and Dupuis 2002). The distributions of the boreal toad (*Bufo boreas boreas*) and the California toad (*B. b. halophilus*) overlap some in northern California.

The boreal toad was once widely distributed in Region 2 from the mountains of southeastern Wyoming through the Rocky Mountains in Colorado to the San Juan Range in northern New Mexico (U.S. Fish and Wildlife Service 1995). We mapped current and historical distributions of boreal toads in Region 2 (**Figure 7, Figure 8, Figure 9, Figure 10, Figure 11**) using occurrence data to modify the predicted distribution from GAP data. Occurrence data were primarily drawn from the Natural Heritage Programs in Wyoming (Wyoming Natural Diversity Database) and Colorado (Colorado Natural Heritage Program), with reference made to GAP (Merrill et al. 1996, Schrupp et al. 2000). Boreal toads were present in 11 mountain ranges distributed throughout Region 2: Park/Sierra

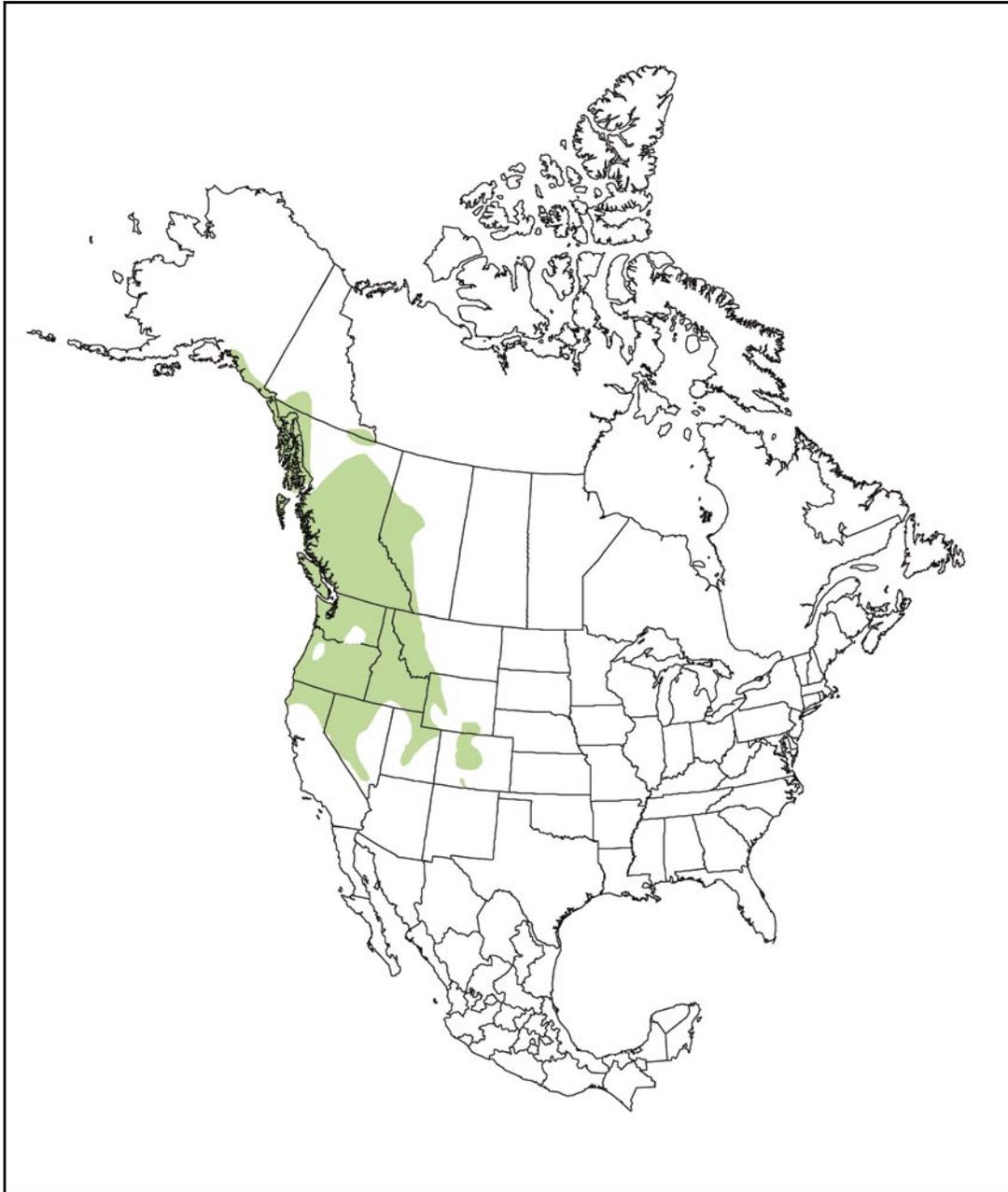


Figure 6. North American range of boreal toad.

Madre Range, Elkhead Mountains, Medicine Bow Range, Front Range, Gore Range, Mosquito and Ten Mile Range, Sawatch Range, White River Plateau, Grand Mesa, Elk and West Elk Mountains, and the San Juan Mountains (**Table 1**). Boreal toads were also historically present in the Wind River and Absaroka ranges in western Fremont and Park counties in Wyoming within Shoshone National Forest.

Although the boreal toad's range has contracted slightly, its distribution within this range has been

greatly reduced, particularly in the Southern Rocky Mountain portion of Region 2. For example:

- ❖ The BTRT reported that in the Southern Rocky Mountains boreal toads are currently present in less than one percent of historic breeding areas (Loeffler 2001). Thus, in addition to range contraction, much apparently suitable habitat within the current range is now unoccupied.

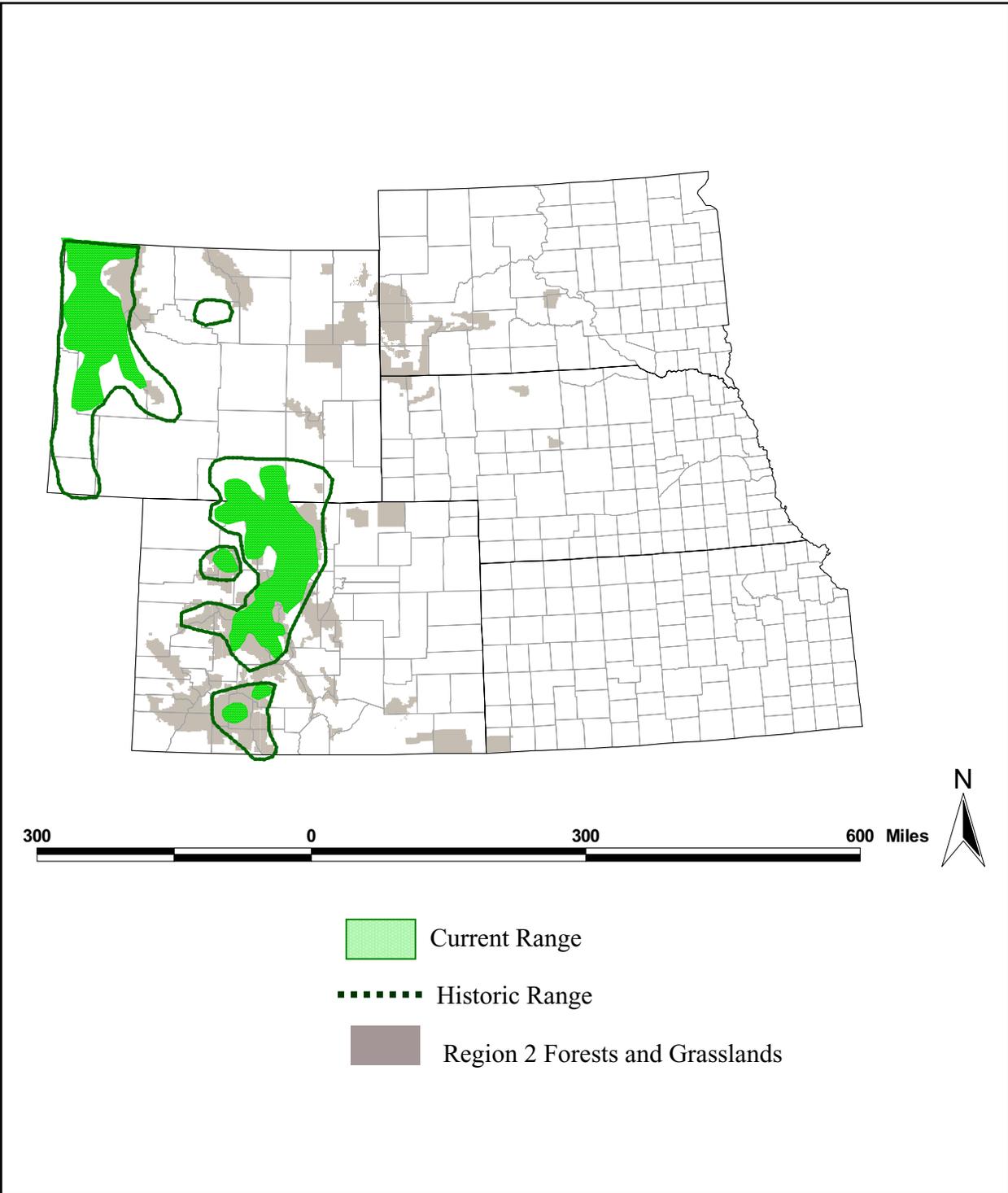


Figure 7. Boreal toad distribution in USDA Forest Service Region 2.

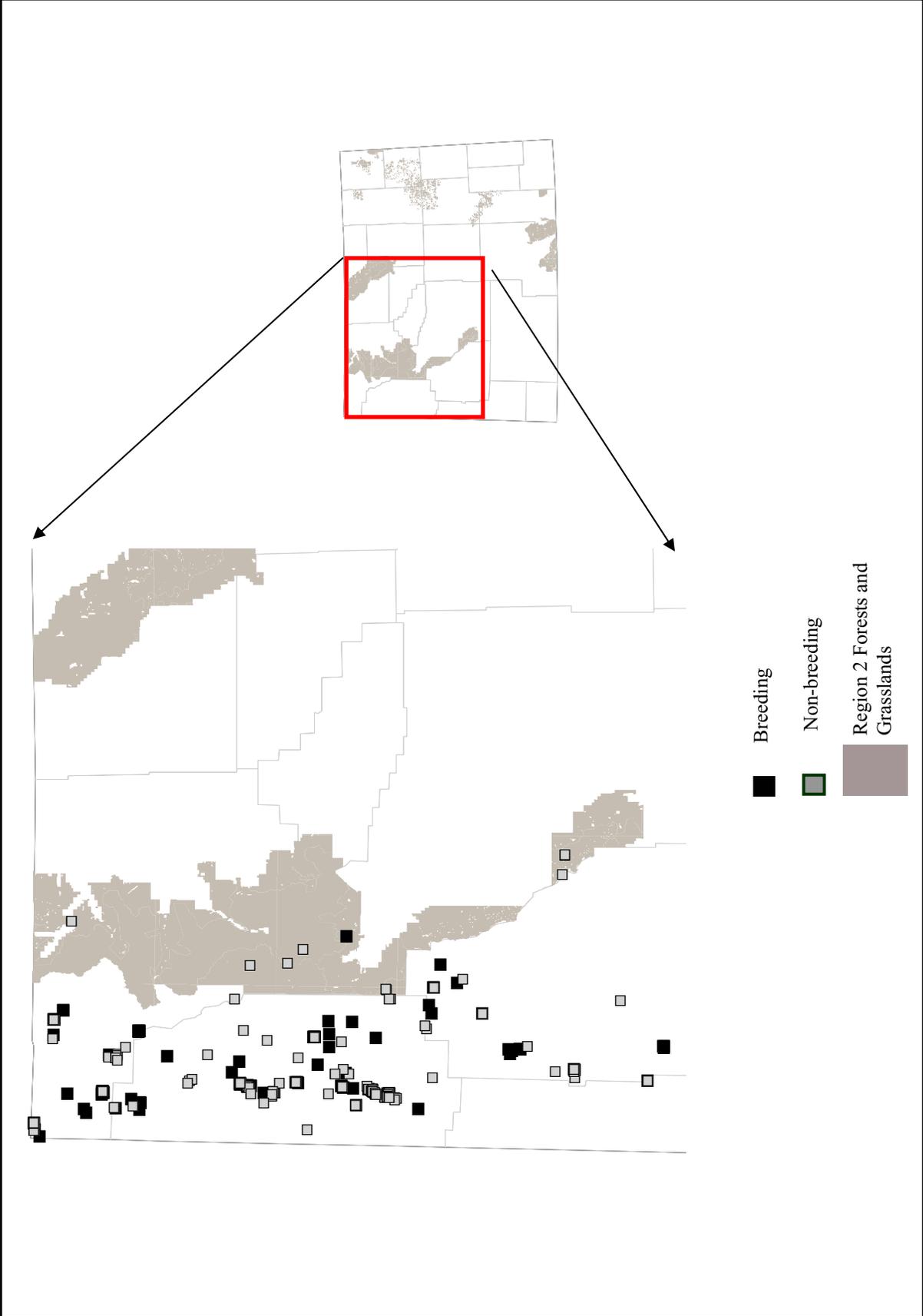


Figure 8. Current (<10 years old) breeding and non-breeding areas for the Northern Rocky Mountain Population of boreal toads in Wyoming.

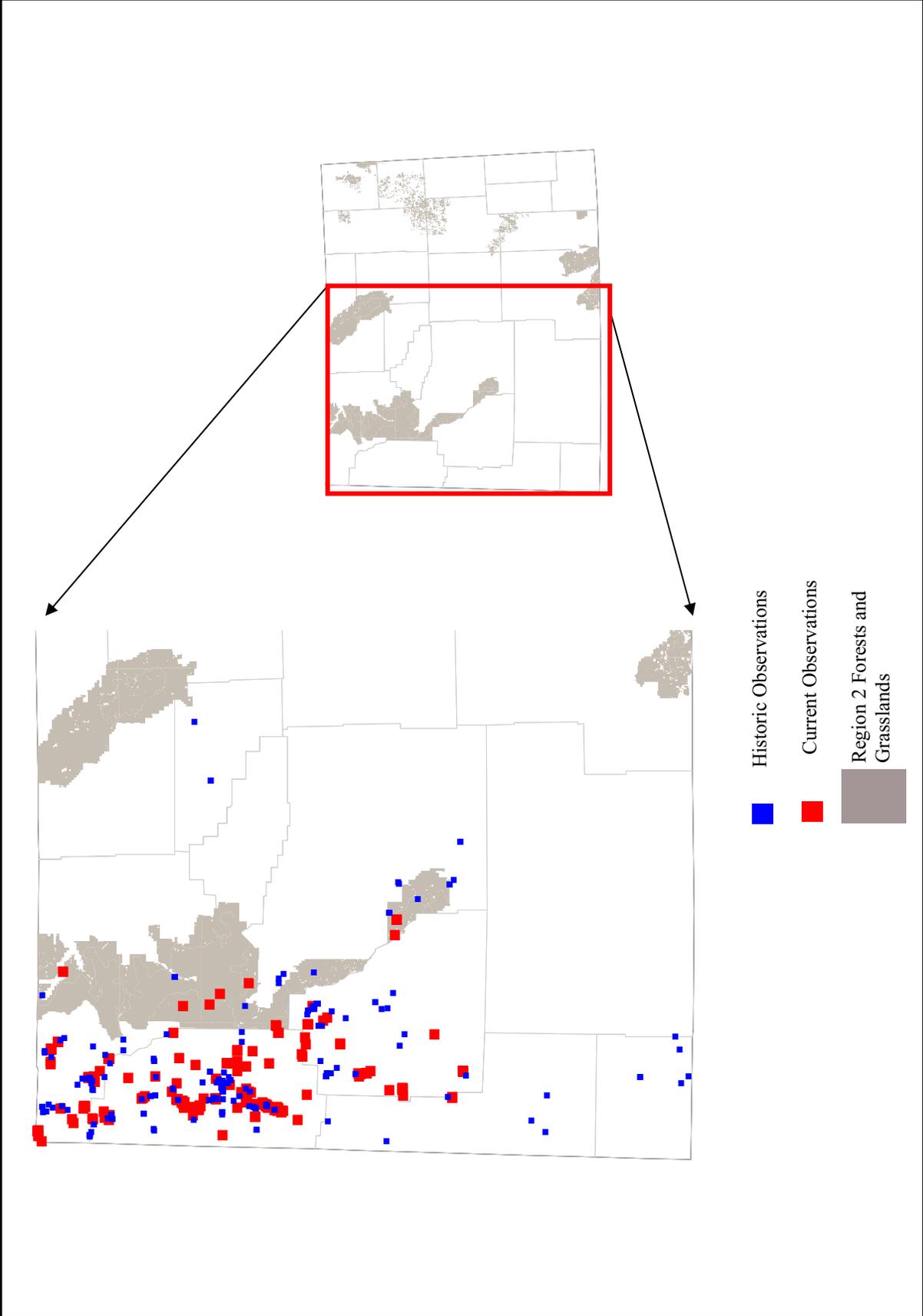


Figure 9. Historic (>10 years old) and current (<10 years old) occurrence data from the Northern Rocky Mountain Population of boreal toads in Wyoming.

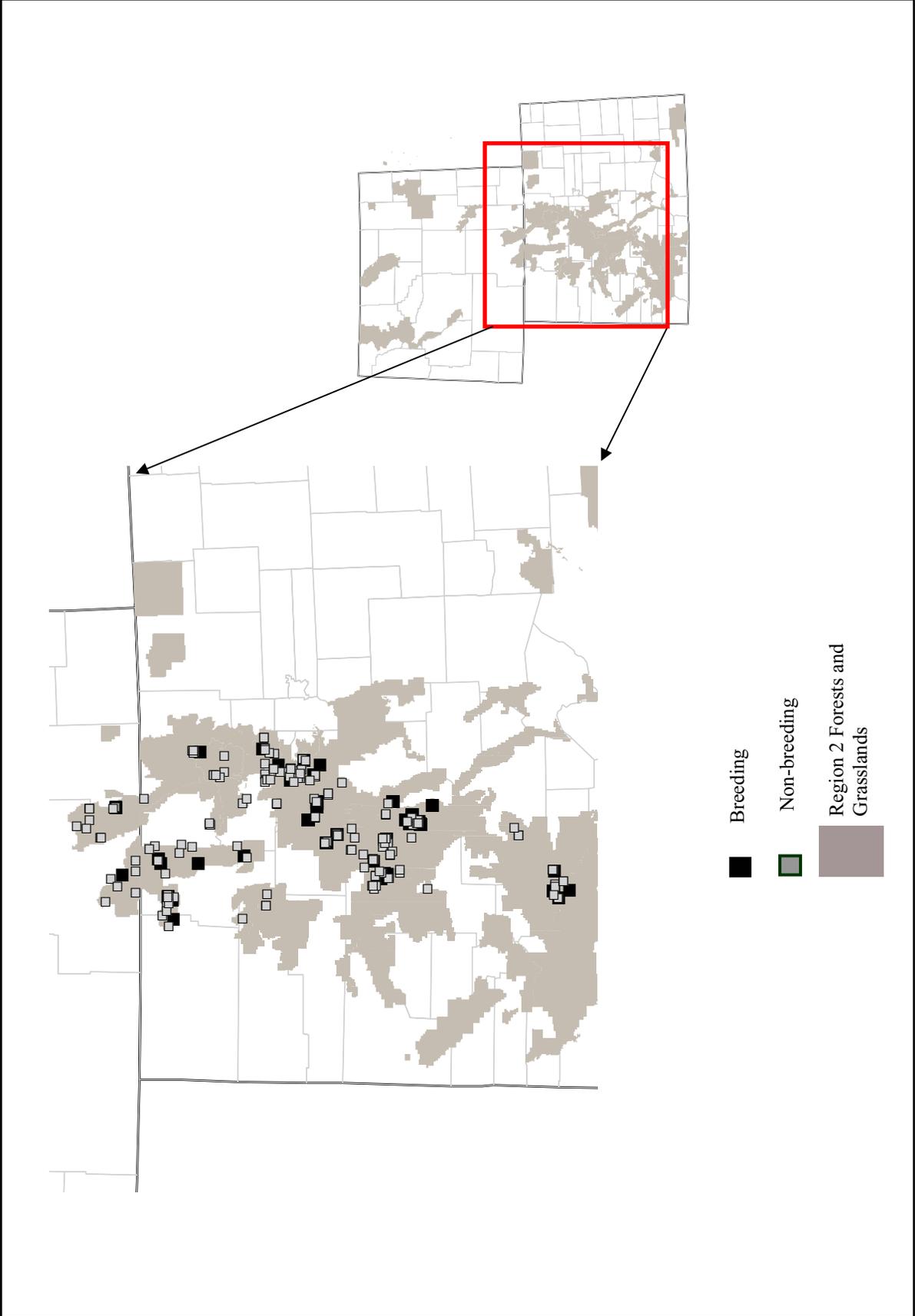


Figure 10. Current (<10 years old) breeding and non-breeding areas for the Southern Rocky Mountain Population of boreal toads in Wyoming and Colorado.

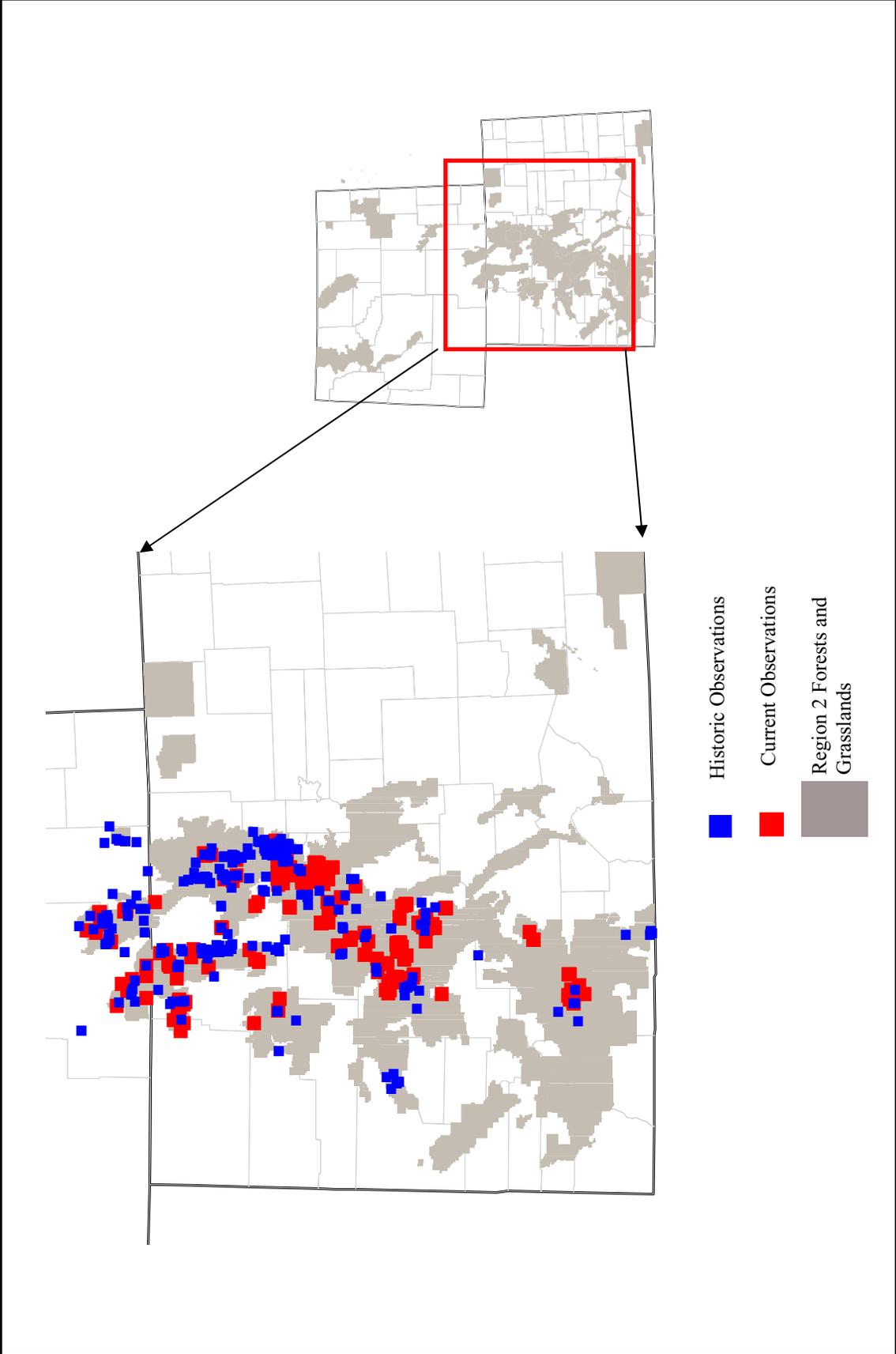


Figure 11. Historic (> 10 years old) and current (< 10 years old) occurrence data from the Southern Rocky Mountain Population of boreal toads (*Bufo boreas boreas*) in Colorado.

Table 1. Description of geographic areas/mountain ranges with historic boreal toad (*Bufo boreas boreas*) occurrences in USDA Forest Service Region 2.

Park Range/ Sierra Madre Range

This area extends from south-central Carbon County, WY, through eastern Jackson County and eastern Routt County, CO, along the continental divide to Rabbit Ears Pass. It is located primarily on the Routt and Medicine Bow National Forests.

Elkhead Mountains

This area is in western Routt County and eastern Moffat County, CO, northeast of Craig, CO. It is located primarily on the Routt National Forest.

Medicine Bow Range

This is an area extending from southeastern Carbon County and western Albany County, WY, south through eastern Jackson County and western Larimer County, CO, to approximately Cameron Pass. It is situated primarily on the Routt and Roosevelt national forests.

Front Range

This is an extensive area in northern Colorado, which includes southwestern Larimer County, eastern and southern Grand County, the western portions of Boulder, Gilpin, and Clear Creek Counties, and eastern Summit County. It extends from the Mummy Range, in the north, south through Rocky Mountain National Park to Loveland Pass and the Mt. Evans Wilderness Area. Much of this area is within the Arapahoe/Roosevelt National Forest.

Gore Range

This area extends from west-central Routt County and northwestern Grand County south to western Summit County, CO, including the Eagle's Nest Wilderness Area. Much of this area is on the White River and Arapahoe national forests.

Mosquito and Ten Mile Range

This area extends from southern Summit County south to the Buffalo Peaks Wilderness Area in western Park County and northeast Chaffee County, CO. Much of it is within the Arapahoe and Pike/San Isabel national forests.

Sawatch Range

This area includes western Lake and Chaffee counties and eastern Pitkin and Gunnison counties, CO, extends from the Holy Cross Wilderness Area south to Monarch Pass, and includes the upper Fryingpan drainage east of eastern Taylor Park. It is located primarily on the White River, San Isabel, and Gunnison national forests.

White River Plateau

This area includes southwestern Routt County, western Rio Blanco County, and northwest Eagle County, CO. It includes the Flat Tops Wilderness and is within the White River National Forest.

Grand Mesa

This area incorporates western Gunnison County, northern Delta County, and eastern Mesa County, CO, and is located primarily on the Grand Mesa and Gunnison national forests.

Elk and West Elk Mountains

This area consists of parts of western and northern Gunnison County west of Taylor Park, and southwest Pitkin County, CO. It includes the Maroon Bells/Snowmass and West Elk wilderness areas.

San Juan Mountains

Mineral, Saguache, western Rio Grande, and Conejos counties in Colorado, and Rio Arriba County in New Mexico. Most of the boreal toad habitat in this area is located on the Gunnison, Rio Grande, San Juan, and Carson national forests.

- ❖ As of August 2002, the SRMP of the boreal toad was known to occur in 14 Colorado counties (Chaffee, Clear Creek, Eagle, Grand, Gunnison, Hinsdale, Jackson, Larimer, Mesa, Mineral, Park, Pitkin, Routt, and Summit) and two counties in southern Wyoming (Albany and Carbon). This is a substantial decrease in the historical distribution documented in Region 2. However, there is some evidence that boreal toads may still occur in Boulder, Conejos, Garfield, Gilpin, Lake, Rio Blanco, and Saguache counties in Colorado.
- ❖ Although boreal toads were historically present in the Medicine Bow, Sierra Madre, and Laramie ranges in Wyoming, they are currently found in only a few isolated areas in Medicine Bow National Forest (Degenhart et al. 1996). The one known breeding population, Bird Creek in Albany County, has been monitored regularly since 1998, and no breeding activity has been documented (Wyoming Game and Fish Department unpublished data). Repeated surveys of the Medicine Bow Mountains during summer 2002 by a collection of concerned groups resulted in only nine observations of boreal toads: two adults at Bird Creek, four juveniles in the upper North Fork of the Little Laramie River in Albany County, two juveniles at Ryan Park, and one juvenile at Phantom Lake in Carbon County.
- ❖ Boreal toads are likely extirpated from the southern periphery of their range in the San Juan Mountains in New Mexico (Stuart and Painter 1994, Degenhart et al. 1996). Surveys conducted from 1997 to 2000 in these areas failed to find any boreal toads in either Rio Arriba County, New Mexico or adjacent Conejos County, Colorado.

Abundance and population trends

In general, there is very little long-term monitoring data for boreal toad populations. We have summarized the information of which we are aware in the following discussion and in **Table 2**. Declines in abundance have been reported throughout the species' range, and large declines have been reported in many areas, especially the Southern Rocky Mountains (Corn et al. 1989, Carey 1993). Boreal toad populations have declined dramatically within Region 2 over the past 25 years. It appears that populations in the Southern Rocky

Mountains (e.g., Colorado, New Mexico, southern Wyoming) have exhibited more drastic declines than populations to the north (e.g., northern Wyoming) (see below). Elsewhere, declines (both in abundance within populations and in the number of populations) have been reported in the Sierra Nevada Mountains (Drost and Fellers 1996), the Pacific Northwest (Blaustein and Olsen 1991, Blaustein et al. 1994, Stebbins and Cohen 1995), and California (Drost and Fellers 1996, Fisher and Shaffer 1996).

The boreal toad was once abundant throughout the Southern Rocky Mountains. In Colorado, reports on boreal toads from the early 1900s through the 1950s described this species as abundant throughout its range in the state (Ellis and Henderson 1915, Burger and Bragg 1947, Blair 1951, Stebbins 1954, Smith et al. 1965). Boreal toads were historically known to occur in 25 of 63 Colorado counties, and they were considered common in eight counties (Boulder, Chaffee, Gilpin, Grand, Gunnison, Hinsdale, Jackson, and Larimer).

Recent reports indicate that over the past 25 years boreal toad populations have declined in Colorado, Utah, southeastern Wyoming, and New Mexico (Corn et al. 1989, Carey 1993, Stuart and Painter 1994, Ross et al. 1995, Corn et al. 1997, Loeffler 2001). The best recent information on population trends in Region 2 indicates that boreal toad populations continue to decline and some populations are becoming extinct. For instance:

- ❖ At the time of their surveys, Corn et al. (1989) observed that boreal toads were absent from 83 percent (49/59) of historic locations in the Front and Park ranges of Colorado and the Medicine Bow Mountains in Wyoming. The same study observed that boreal toad populations inside Rocky Mountain National Park appeared to be surviving better than those outside. Boreal toads were observed at 10 percent (5/48) of the historically known sites outside the park and 45 percent (5/11) of the known sites inside the park. Recently these populations inside Rocky Mountain National Park have declined dramatically (R. Scherer personal communication 2002).
- ❖ Boreal toads were once common throughout the Elk and West Elk mountains of western Colorado (Burger and Bragg 1947), but Carey (1993) observed declines in the boreal toad populations in this region of Colorado

Table 2. Summary status of known boreal toad (*Bufo boreas boreas*) breeding sites in the southern Rocky Mountains of Wyoming and Colorado. Information adapted from Boreal Toad Recovery Team (2003).

Location	Breeding Population				
	Monitoring period ¹	Maximum (Year) ²	Most recent ²	2002 Recruitment ³	Chytrid Presence ⁴
<u>Park Range, CO</u>					
Soda Creek	1996-2003	1 (1996)	0	Unknown	—
Diamond Park, North Fork Elk River	1996-2003	1 (1996)	0	Unknown	—
Upper Buck Mountain, North Fork Elk River	2000-2003	6 (2003)	6	Yes	No
Spike Lake, Red Canyon	2001-2003	1 (2001)	0	Unknown	—
<u>Elkhead Mountains, CO</u>					
First Creek, California Park	1995-2003	1 (1996)	0	No	—
Torso Creek, California Park	1999-2003	2 (2000)	2	Yes	2001
<u>Medicine Bow Range, WY</u>					
Bird Creek, Albany County	1993-2003	3 (1997)	0	Unknown	—
<u>Front Range, CO</u>					
Lost Lake, Rocky Mountain National Park	1990-2003	35 (1994)	0	Unknown	2000
Kettle Tarn, Rocky Mountain National Park	1990-2003	25 (1993)	3	Yes	2000
Spruce Lake, Rocky Mountain National Park	1996-2003	4 (2000)	1	Unknown	No
Glacier Basin, Rocky Mountain National Park	1995-2001	1 (1996)	0	Unknown	—
Twin Lake, South Cache la Poudre	1998-2003	2 (2001)	0	Unknown	2001
Lost Lake, Middle Boulder Creek	1996-2003	0 (-)	0	Unknown	—
Jim Creek, Winter Park	1995-2003	1 (1995)	0	Unknown	—
Pole Creek, Pole Creek	1995-2003	7 (2001)	2	Yes	2000
Vasquez Creek, Vasquez Creek	1999-2003	1 (1999)	0	Unknown	—
McQueary Lake, Upper Williams Fork	2001-2003	6 (2002)	2	Unknown	2003
Upper Williams Fork, Upper Williams Fork	2001-2003	2 (2001)	1	Yes	No
Montezuma, Snake River	1995-2002	1 (1995)	0	Unknown	—
Peru Creek, Snake River	1996-2002	2 (1997)	1	Unknown	2001
Upper North Fork of Snake River	1998-2003	1 (2002)	1	Unknown	2001
Lower North Fork of Snake River	1998-2003	1 (1998)	0	Unknown	—
Straight Creek, Snake River	2003 only	1 (2003)	1	Unknown	No
Vintage, West Fork Clear Creek	1994-2003	2 (1995)	0	Unknown	—
Urad-Henderson, West Fork Clear Creek	1995-2003	107 (1998)	15	Unknown	2001
Herman Gulch, Clear Creek	1993-2003	12 (1996)	1	Unknown	No
Mount Bethel, Clear Creek	1993-2003	6 (2001)	7	Yes	No
Bakerville, Clear Creek	1994-2003	1 (2003)	1	Unknown	—
Silverdale, Clear Creek South	1993-2001	0 (-)	0	Unknown	No
Otter Mountain, Clear Creek South	2003 only	1 (2003)	1	Unknown	No
<u>Gore Range, CO</u>					
North Fork Morrison Creek	1999-2003	10 (2001)	1	Unknown	No
East Vail	1999-2003	4 (2001)	1	Unknown	No
Upper North Tenmile Creek	1995-2003	8 (2002)	1	Unknown	No
Lower North Tenmile Creek	1996-2003	5 (1998)	2	Yes	No
<u>Mosquito and Ten-Mile Ranges, CO</u>					
Cucumber Gulch, Breckenridge	1995-2003	1 (1999)	0	Unknown	—
Fourmile Creek, Buffalo Peaks	1995-2003	4 (2001)	3	Unknown	No

Table 2 (Concluded).

Location	Breeding Population				
	Monitoring period ¹	Maximum (Year) ²	Most recent ²	2002 Recruitment ³	Chytrid Presence ⁴
<u>Sawatch Range, CO</u>					
Collegiate Peaks Campground, Cottonwood Creek	1993-2003	8 (1997)	5	Yes	No
Denny Creek, Cottonwood Creek	1994-2003	23 (2000)	22	Unknown	No
Hartenstein Lake, Cottonwood Creek	1994-2003	14 (2000)	7	Unknown	No
South Cottonwood Creek	1995-2003	11 (1999)	4	Yes	No
Brown's Creek	1995-2003	4 (1996)	0	Unknown	No
Kroenke Lake, Cottonwood Creek	1995-2003	3 (2003)	3	Yes	No
Morgan's Gulch, Cottonwood Creek	1997-2003	7 (2003)	7	Unknown	No
Sayer's Gulch, South Fork Lake Creek	1997-2003	6 (2002)	4	Yes	No
West South Cottonwood Creek	1998-2003	9 (2000)	6	Yes	No
Rainbow Lake, Cottonwood Creek	1999-2003	3 (1999)	1	Unknown	—
Middle Cottonwood Creek	1999-2003	5 (2003)	5	Yes	No
Denny Creek West, Cottonwood Creek	1999-2003	2 (2003)	2	Unknown	No
Denny Creek South, Cottonwood Creek	1999-2003	2 (2001)	0	No	No
Holywater Beaver Ponds, Cottonwood Creek	2002-2003	3 (2002)	1	Yes	No
Holy Cross City	1996-2003	2 (1998)	1	Unknown	No
East Lake Creek	1996-2003	4 (1999)	2	Unknown	No
Strawberry Lakes, Holly Cross City	2003 only	1 (2003)	1	Unknown	No
Magdalene Gulch, Texas Creek	1999-2003	1 (1999)	0	Unknown	No
White River Plateau	Not surveyed				
Grand Mesa (some survey, no toads found)	Not monitored	0 (-)	0	Unknown	—
<u>Elk and West Elk Mountains, CO</u>					
Conundrum Creek	1995-2003	3 (2001)	0	Unknown	2001
East Maroon Creek, Conundrum Creek	2000-2003	3 (2003)	3	Unknown	No
Triangle Pass, White Rock Mountains	1993-2003	16 (2002)	14	Yes	No
West Brush Creek, White Rock Mountains	1999-2003	1 (1999)	0	Unknown	—
Brush Creek, White Rock Mountains	2000-2003	5 (2002)	2	Yes	No
<u>San Juan Mountains, CO</u>					
Jumper Creek, Trout Creek	1994-2003	3 (1997)	1	Yes	No
Trout Creek, Trout Creek	1996-2003	1 (1996)	0	Unknown	—
Roaring Fork Pond, Goose Creek	2000-2003	1 (2002)	0	Unknown	No
West Trout Creek, Trout Creek	2000-2003	5 (2003)	5	Yes	No
Average Current Breeding Population Size for Chytrid-Positive Sites			2.6 (range 0-15; n=10)		
Average Current Breeding Population Size for Unknown Chytrid Sites			0.2 (range 0-1; n=19)		
Average Current Breeding Population Size for Chytrid-Negative Sites			3.4 (range 0-22; n=35)		

¹ Regular survey visits began at about the time the boreal toad became listed as endangered in Colorado (1993), but there is some variation in when particular populations were visited.

² A breeding population is herein defined as one breeding pair (one adult female and one adult male) and at least one resulting egg mass. Thus, "2" means that at least two females and two males were present at the site and at least one egg mass was found. The maximum breeding population is the largest breeding population documented during the monitoring period, followed parenthetically by the year it occurred; if two or more years had the same figure, the latest year is presented. The current breeding population is refers to results of the latest survey year.

³ As noted by Boreal Toad Recovery Team (2003, p. 12): "Yes" means that one-year-old toadlets were observed at the site in the Spring of the following year, or two-year-old toads were seen the second year. For example; one-year-old toadlets in June 1997 would indicate successful recruitment from the 1996 breeding season, and would be noted by a "Yes" entry in 1996."

⁴ A date indicates that chytrid was documented at the locality at that time. "No" indicates that no chytrid-positive toads have yet been documented at the locality. "—" means that the site has not yet been tested for the presence of chytrid fungus.

and documented the extinction of 11 distinct populations of boreal toads in the West Elk Mountains between 1974 and 1982. More recent and intensive surveys have revealed a few remaining, but restricted, populations (L.J. Livo personal communication 2002).

- ❖ Surveys of 38 historic breeding sites conducted between 1982 and 1992 on eight national forests in Colorado revealed only one occupied site (Loeffler 2001).
- ❖ Hammerson (1989) surveyed 250 sites in Colorado in Jackson, Garfield, Rio Blanco, Moffat, Routt, Delta, Mesa, Chaffee, Clear Creek, Gilpin, Gunnison, and Garfield counties and observed boreal toads in only two of the areas surveyed (Chaffee and Garfield counties). Following this study, Hammerson (1992) surveyed an additional 377 sites in the following Colorado counties or river basins: Upper Alamosa, Upper Arkansas, Conejos, Upper Eagle, Grand County, Grand Mesa, Upper Gunnison, Upper Rio Grande, San Juan, San Luis Valley, Upper San Miguel, and Upper South Platte, and observed only one population.
- ❖ Corn et al. (1989) observed that boreal toads were absent from 83 percent of historic locations in Colorado and 94 percent of historic sites in Wyoming.

During the past five years, breeding populations were documented in 12 counties in Colorado and one county in Wyoming (Boreal Toad Recovery Team 2003). There are presently 60 known breeding localities located in nine of 11 geographic areas where boreal toads were known to occur historically. Based on the criteria established by Loeffler (Boreal Toad Recovery Team 1998), the 60 breeding localities comprise 32 separate populations, of which only one population, in the Sawatch Range, presently meets the BTRT criteria to be considered a viable breeding population. Die-offs caused by the chytrid fungus *Batrachochytrium dendrobatidis* have greatly reduced two populations, which were considered viable until recently (Boreal Toad Recovery Team 2003).

Historically, boreal toads were considered common within the NRMP. Carpenter (1953) reported that the boreal toad was “the most wide-spread amphibian in the region”, and Turner (1955) reported observing large numbers of boreal toads near Fishing

Bridge and Lake Lodge in Yellowstone National Park. In general, the NRMP of boreal toad appears to have been more abundant historically than currently, but it does not appear to be declining as rapidly as the SRMP. However, since there has been relatively little coordinated effort to inventory and monitor the NRMP in Wyoming, these conclusions are mainly conjecture. Large regions of potential boreal toad habitat in the Bridger-Teton and Shoshone national forests (the Wind River, Absaroka, and Wyoming ranges) have not been systematically surveyed. Much of the research on the NRMP has taken place in parts of the Greater Yellowstone Ecosystem (Patla and Peterson 1999, Bartelt 2000, Hawk 2000, Patla 2000a, Patla 2000b, Van Kirk et al. 2000, Patla 2001) or neighboring states (Werner and Reichel 1994, Reichel 1995, Hendricks and Reichel 1996, Reichel 1996, Werner and Reichel 1996, Reichel 1997, Werner et al. 1998), but inferences can be made to populations on nearby Region 2 forests. Some reported evidence follows:

- ❖ Surveys conducted in the late 1990s indicated that boreal toads were absent from a large number of historic locations, and that they occupied a small proportion of the available suitable habitats (Werner and Reichel 1994, Reichel 1995, Hendricks and Reichel 1996, Reichel 1996, Werner and Reichel 1996, Reichel 1997, Werner et al. 1998).
- ❖ Recent assessments of amphibians in the Greater Yellowstone Ecosystem (Patla and Peterson 1999, Van Kirk et al. 2000) indicate that boreal toads have declined in both northern Wyoming and southeastern Idaho compared to historical records.
- ❖ Declines have been reported in both Grand Teton and Yellowstone national parks, based on comparisons between early reports by Carpenter (1953) and Turner (1955) and recent surveys by Koch and Peterson (1995) and Patla and Peterson (1999). These surveys suggest that the NRMP of boreal toads is less abundant but still present in historic areas (Peterson et al. 1992, Koch and Peterson 1995).
- ❖ Surveys in Montana during the 1990s indicated that boreal toads were absent from a large number of historical sites and that although they were still widespread across the landscape, they occupied a small proportion of suitable habitat (<10 percent)

(Werner and Reichel 1994, Reichel 1995, Hendricks and Reichel 1996, Koch et al. 1996, Reichel 1996, Werner and Reichel 1996, Reichel 1997, Werner et al. 1998).

- ❖ Recent surveys by Maxell (2000) found boreal toads to be widespread but rare in watersheds across western Montana. They were found in only 27 percent (11/40) of the watersheds surveyed, and breeding was observed in only 21 percent (7/33) of the watersheds with suitable breeding habitat. Additionally, boreal toads were found in only 3.7 percent (13/347) of the standing water bodies that were surveyed. Similar surveys conducted in 1999-2000 at 400 sites in Glacier National Park found boreal toads at less than 5 percent of the sites surveyed; and surveys on the Flathead Indian Reservation found boreal toads at only four of nine sites where they were historically observed (Maxell 2000).

Activity and movement

During the spring and at high elevations, adult boreal toads are mainly active diurnally but may be active during crepuscular or nocturnal hours when conditions are suitable. During warmer months, adult activity can occur during any time of day or night, but it appears to peak in the evening. In general, metamorphs are active almost exclusively diurnally (Sullivan et al. 1996), presumably because they lack the body mass to retain body temperature during the night. Toads seek out warm areas for basking on cool days and may seek shelter in cool microhabitat areas such as small animal burrows, soft mud, or under rocks and logs during the hottest parts of the day. Bartelt (2000) tracked boreal toad activity patterns using radio telemetry on the Targhee National Forest. He observed considerable individual variation in activity patterns between toads. Surface activity rates peaked between 2100 and 2400 hours, and toads were active in a wide range of temperatures (-2 °C to 27 °C) and humidity levels (60 to 100 percent). The distances moved by toads increased during the night as they moved from daily sheltered sites to water or warm substrates. A majority of boreal toad daily movements were less than 50 meters, and the greatest single day movement recorded was 439 meters. Feeding activity peaked during mid-day, and all activity increased as humidity rose above 75 percent.

Research by Bartelt (2000) on the Targhee National Forest also indicates that adult female boreal

toads are more likely to disperse from breeding sites than males. Six of eight female toads left the pond after breeding while only two of ten males dispersed. On average, the females disperse farther from breeding sites than males also – 2.4 km and 0.9 km, respectively. Bartelt (2000) speculated that this differential movement between males and females was the result of stronger fidelity to breeding sites among males, and that females may be traveling longer distances to access preferred foraging sites. Fidelity to a breeding site may increase a male's ability to compete for mates each spring. In comparison, females have very high energetic needs in order to produce an egg clutch. Female toads at higher elevation may require two or more seasons of feeding to produce a single clutch (Campbell 1970). In these studies, juvenile boreal toads have been documented dispersing into terrestrial habitats similarly to adults. Evidence from research in Rocky Mountain National Park (Corn et al. 1997) shows that boreal toads moved between two small populations approximately 5 to 6 miles apart indicating, that they are capable of even longer dispersal than that observed by Bartelt (2000).

Campbell (1970) reported that boreal toads in Colorado moved 900 meters from summer breeding areas to hibernacula during late September and remained in the hibernacula till the following May, shortly after snowmelt. More than 30 boreal toads occupied the same hibernaculum, which was a small chamber in rocky till (Campbell 1970). Boreal toads may also use abandoned rodent burrows for hibernacula. They may emerge from their hibernacula periodically during September and October to bask near the entrance on warm days (Hammerson 1999). Boreal toad activity increases after the snow melts as they move to breeding sites during May and June in the Rocky Mountains. Bartelt (2000) recorded that boreal toad movements to and from breeding sites followed linear paths out and back to the breeding areas.

Based on evidence of feasible dispersal distances, the SRMP of boreal toads is isolated from populations in the Wasatch and Uinta mountains of Utah and the Wind River and Salt River ranges in Wyoming by physical and climatic characteristics in the dry basins that lay between these populations. The distance (>100 miles) between these areas, as well as the habitat in riparian areas that exists along rivers at low elevations (e.g., warmer, dryer, and drastically different vegetation structure) create a barrier to the movement of boreal toads. Therefore, it appears that there is little or no potential for connectivity between the SRMP and the NRMP due to inadequate habitat in these dry basins. However, the NRMP appears to be

contiguous with boreal toad populations in the Pacific Northwest and Canada.

There is no conclusive evidence to suggest that there are regional differences in boreal toad migration patterns in Region 2 states. Movement patterns between breeding sites and hibernacula appear to be similar for both the NRMP and SRMP in Region 2.

Habitat

General requirements

Boreal toads live in a wide range of habitats in western North America: wetlands, forests, woodlands, sagebrush, meadows, and floodplains in the mountains and valleys (Carpenter 1953, Campbell 1970, Black 1971, Stebbins 1985). While they primarily use wetland habitats (**Figure 12**), boreal toads may be observed in other habitats during dispersal to and from breeding sites. Although they have been observed in a wide range of elevations (from sea level to near or above tree line), boreal toads generally occur between 2,250 and 3,600 m (7,500 and 12,000 ft.) in Region 2 (Campbell 1970, Stebbins 1985, Livo and Yackley 1997, Hammerson 1999). This species is usually found in wetlands near ponds, lakes, reservoirs, rivers, and streams, and it is typically less common in densely forested areas (**Figure 12**; Campbell 1970, Hammerson 1999). The wetland habitat classification system of Cowardin et al. (1979) defines the following wetland classes: aquatic bed, streambed, rocky shore, unconsolidated shore, emergent wetland (persistent and non-persistent), scrub-shrub wetland, and forested wetland. These wetland classes are likely to be used by boreal toads based upon the general habitat use patterns described by Campbell (1970). Boreal toads are likely to be found within these classes in Riverine, Lacustrine, and Palustrine wetland systems. The terrestrial habitat classification system of Grossman et al. (1998) defines the following habitat classes that boreal toads are likely to use: Herbaceous, Forest, Woodland, and Shrubland. In Wyoming, boreal toads use wet habitats in foothills, montane, and subalpine areas, and they are seldom far from water (Baxter and Stone 1985). They may be found in all riparian habitat types (Gerhart and Olson 1982).

Seasonal and life history shifts

Boreal toads occupy three distinct types of habitats during the course of a year: 1) breeding ponds, 2) summer range, and 3) over-winter hibernacula. In the early summer, breeding adult boreal toads are found in or near water, and as the season progresses they may

use more terrestrial habitats (Campbell 1970). Breeding habitats typically include shallow water (<20 cm) at the edges of ponds and lakes, stream and river edges where the water is pooled or very slow moving, oxbow ponds, thermal pools and streams, flooded meadows, ephemeral pools, abandoned and active beaver (*Castor canadensis*) ponds, and man-made impoundments including reservoirs and quarries (Patla 2001). Hawk (2000) observed that breeding sites for boreal toads in the Greater Yellowstone Ecosystem have waters with relatively high conductivity. Koch and Peterson (1995) also observed that the water of boreal toad breeding sites generally has a high pH (>8.0) and high acid neutralizing capacity. Hawk (2000) hypothesized that thermally influenced waters with high conductivity may provide some protection from bacterial infections.

There are no empirical data to suggest that boreal toads select specific water body types or sizes for breeding. Boreal toads have been documented breeding in large permanent lakes, glacial kettle ponds, man-made ponds, beaver ponds, marshes, and roadside ditches. However, egg and tadpole development are temperature dependent. The period between hatching and metamorphosis may be as long as 92 days in cold-water habitat (Livo 1999). Females deposit eggs in shallow, calm water that optimizes the thermal effects of the sun, allowing eggs to mature to hatching faster than the typical ambient water temperature would allow (Loeffler 2001). The water temperature at breeding sites typically ranges from 15 to 21 °C (59 to 70 °F) (Campbell 1970).

Terrestrial habitats occupied by boreal toads in the summer after breeding include a diversity of forested and non-forested wet and dry areas. Adult boreal toads have been observed spending up to 90 percent of their life in upland terrestrial habitats (Jones et al. 2000). Bartelt (2000) observed that radio-tagged boreal toads occupied underground burrows over 26 percent of the time. Bartelt (2000) also observed that willows, woody debris, and breaks in the shrub or tree canopy layers that allowed sunlight to reach the ground were also frequently used terrestrial habitat features. Research at the Henderson Mine site in Clear Creek County, Colorado investigated boreal toad habitat use and movements of adult toads that were fitted with passive integrated transponders (PIT tags) and radio transmitters. This research indicates that slope is not a deterrent to boreal toad movements in upland habitats, and that toads frequently occupy terrestrial habitats outside the relatively flat wetland areas, which previously were thought to be their primary terrestrial habitat. There also appears to be a great

(A)



(B)

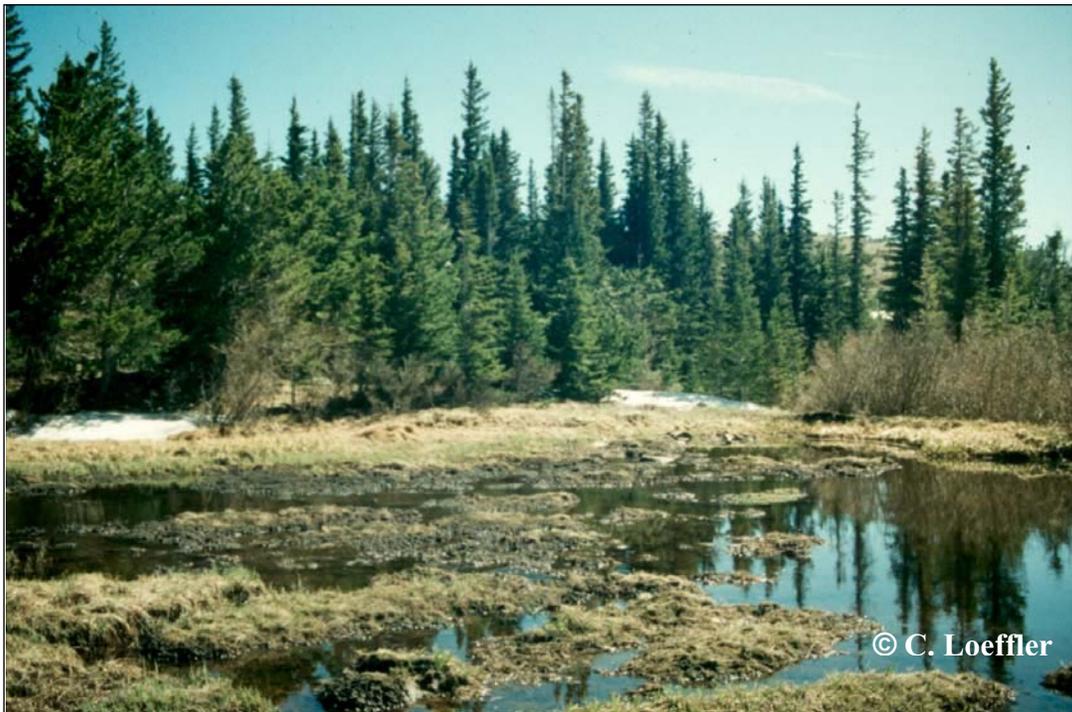


Figure 12. Boreal toad habitat: (A) Denny Creek, Chaffee County, Colorado; (B) near Caribou, Boulder County, Colorado (Photos by Chuck Loeffler).

deal of heterogeneity among individuals in regards to habitat preferences. Some toads were observed using a single habitat type, such as conifer forest, while others moved frequently and used a variety of habitats (Jones et al. 2000).

During the larval stage, boreal toads are limited to aquatic habitats until metamorphosis, which occurs approximately 75 days after hatching (Boreal Toad Recovery Team 1998). In Region 2 metamorphosis occurs from July to August (Loeffler 2001, Patla 2001). Relatively little is known about the habitat use patterns of metamorphs. Many researchers have observed post-metamorphic basking behavior among recently metamorphosed toads (e.g., Black and Black 1969, Lillywhite 1974). Metamorphs were documented in aggregations of 50 to 1000, in some cases piled two to three deep on the narrow muddy banks along the edge of a wetland. These aggregations appeared to occur in areas with good exposure to sunlight and may provide some benefit in thermoregulation since temperatures in some aggregations were higher than ambient air and water temperatures (Black and Black 1969). Following metamorphosis, juvenile boreal toads migrate away from aquatic areas and use moist terrestrial habitats. Metamorphs have been documented sheltering under moist woody debris, in underground cavities, and under each other in large aggregations. There is not much information on the habitat use of boreal toads between the juvenile and breeding adult stages.

In early fall, adults and young of the year migrate to terrestrial hibernacula, which are typically burrows made by other animals, such as rodents. Boreal toads also commonly over-winter beneath debris piles, such as rockslides or deadfall timber. On the National Elk Refuge, Patla (2000b) observed boreal toads using streamside cavities and old rodent burrows for hibernation sites. Bartelt and Peterson (1997) documented radio-tagged boreal toads using underground burrows within 1 mile of a small flowing stream and under a slash pile on the Targhee National Forest. Boreal toads in Colorado have been observed using underground chambers near creeks, ground squirrel burrows, and beaver lodges/dams where flowing water keeps the air temperature above freezing (Boreal Toad Recovery Team 1998). Boreal toads do not hibernate in the water like spotted frogs (*Rana luteiventris*) or leopard frogs (*Rana pipiens*), nor are they able to tolerate freezing as do boreal chorus frogs (*Pseudacris triseriata maculata*).

Patterns of microhabitat use are highly variable between areas due to differences in the configuration of local landscape features. Thermal and moisture

conditions at the microhabitat scale influence habitat use patterns for breeding, movement, resting, and foraging during the three main seasons mentioned above (Bartelt 2000, Loeffler 2001). Bartelt (2000) observed that extensive use of terrestrial habitats and long distance travel characterized boreal toads. He observed them moving through terrestrial habitats that contained a variety of microhabitats. The radio-tagged toads that Bartelt tracked chose protected microhabitats that had greater amounts of shrub cover than would have been predicted by the available habitat composition. These selected sites provided protection from evaporative water loss and met their needs for behavioral thermoregulation (e.g., shrub habitats and warm sites for basking, with moist ground litter for cooling).

Area requirements

In general, boreal toad area requirements are relatively localized areas during breeding and hibernation seasons. Their area requirements are larger between breeding and hibernation, when they may travel long distances away from breeding sites and use terrestrial habitats extensively (Bartelt 2000). Campbell (1970) documented home ranges of two boreal toad populations in Boulder County, Colorado and observed that the size of home ranges varied greatly in relation to the amount of available habitat, the number of toads in the population, and the sex of the toads. In general, toad home ranges were larger in areas with greater amounts of quality habitat. This suggests that high population densities in some areas may not indicate high quality habitat; rather, high densities could be due to a limited concentration of marginal habitat in otherwise poor areas. This observation could be the result of differences between the habitats of the surveyed toad populations, and it may not be indicative of all boreal toad populations' area requirements. Campbell (1970) also observed that home ranges were larger in a population with fewer boreal toads and hypothesized that the lower density in this population allowed toads to occupy larger home ranges. It is also apparent from the data collected on these two populations that the population that consisted of a larger proportion of males had larger average home ranges than the population that consisted of a larger proportion of females. It is important to note that all of these observations may be confounded by habitat variables such as water quality, vegetative cover, or prey availability. The population tracked at Albion consisted of 29 boreal toads (75M:25F) and had a larger area of available habitat. The average home range size was 516 m². In comparison, the other population tracked consisted of 50 boreal toads (14M:86F) and had

a smaller area of available habitat. The average home range size for this population was 198 m².

Landscape context

Boreal toads require three main habitat components: 1) shallow wetlands for breeding, 2) terrestrial habitats with vegetative cover for foraging, and 3) burrows for winter hibernation (Loeffler 2001). There is no detailed information on the relative proportion of these habitat types required by boreal toads in Region 2. However, research on habitat use of boreal toads in the Southern Rocky Mountains indicates that the landscape surrounding the breeding site is as important for survival as the breeding site itself. In general, the optimal spatial mosaic of boreal toad habitats in Region 2 includes permanent ponds or wetlands with shallow sunny margins, adjoining willow thickets or shrub cover, and upland montane forests within an elevation range between 8,000 and 11,000 ft. (2,440 and 3,350 m) (Loeffler 2001). Additionally, all of these habitat components must be within a relatively clustered arrangement on the landscape to allow boreal toads to survive. Boreal toads may migrate up to 2.5 km from breeding ponds to winter hibernacula, but in most cases this distance is much less. Therefore, all habitat components should be well within 2.5 km of breeding ponds to provide optimal habitat.

The same spatial limitations may apply to boreal toad dispersal between breeding sites, and suitable habitat for dispersal (e.g. shrub or forest cover, small wetlands, no barriers) would be required to allow for exchange between metapopulations. This connectivity is essential for survival of boreal toads on a regional scale because isolated populations are inevitably more vulnerable to extinction from stochastic events. A majority of existing boreal toad populations and potential boreal toad habitat in the Southern Rocky Mountains are located on USDA Forest Service lands and in Rocky Mountain National Park. Therefore, efforts to protect habitat for boreal toads from the metapopulation to the ecosystem scale should focus on the preservation of the essential components of habitat described above.

Food habits

Observations of boreal toads feeding in the wild indicate that any moving animal smaller than the toad itself is a potential food item (Campbell 1970). The wide variety of food items used by boreal toads indicates that they have a relatively flexible diet and appear to feed primarily on abundant, easy-to-catch prey.

Boreal toad larvae may filter suspended organic material and/or feed on bottom detritus as well as dead tadpoles or adults (Black 1970, Franz 1971, Boreal Toad Recovery Team 1998). Following metamorphosis, the boreal toad diet consists mainly of ground-dwelling coleopterans and hymenopterans, which occur throughout aquatic and riparian habitats in the western United States. Detailed descriptions and references for the natural history of coleopterans and hymenopterans are available in the following sources (Muesebeck 1951, Arnet 1968, Crowson 1981, Darlington and Ball 1985, Hölldobler and Wilson 1990). Despite the dominance of these two taxa in boreal toad diets, a wide variety of invertebrates, including ants, beetles, spiders, mosquitoes, grasshoppers, crane flies, stink bugs, damsel bugs, deer flies, wasps, bees, water striders, alder flies, backswimmers, muscid flies, mites, and snails, are taken as prey (Moore and Strickland 1955, Mullaly 1958, Livezey 1961, Campbell 1970, Miller 1975, Hammerson 1999). Boreal toads also eat small vertebrates including juveniles of their own species (Cunningham 1954). Bartelt (2000) observed that 75 percent of the organic content of boreal toad scats was remains of harvester ants (*Pogonomymes* spp.), 24 percent was beetles, and the remaining 1 percent was wasps (Bracnidae and Isoptera). Campbell (1970) also observed that ants were the principal prey item, with beetles and spiders also making up a significant portion of the diet of boreal toads along the Front Range of Colorado. Campbell observed at least 43 invertebrate families represented in the diet of boreal toads from one study site in Upper Left-hand Park, Boulder County, Colorado.

Boreal toads feed during both day and night hours; however, Campbell (1970) observed that boreal toads may be more successful feeding during daylight based upon the increase of non-food items present in the stomachs of boreal toads feeding at night. Non-food items, such as spruce or fir needles and quartz grains, are carried to the mouth on the toad's sticky tongue when it misses prey on the first strike. Adult boreal toads may use olfactory cues to locate prey items (Shinn and Dole 1979, Dole et al 1981), and they usually sit and wait for prey to come within 2 inches before striking at the prey with their tongue. Campbell (1970) observed that males tended to be more sedentary while feeding and to consume more prey than females, which were more mobile and utilized a wide range of microhabitats. There is no research on the relative value of food items or that may influence prey selection for boreal toads. The food habits described here appear to be consistent across the range of the boreal toad in Region 2.

Breeding biology

Breeding phenology

Breeding activity may begin soon after adult toads emerge from hibernation (usually May), or it may be delayed until later in the summer (July or later) depending on elevation, weather conditions, and the thermal and physical characteristics of the breeding site. Breeding activity is delayed at high elevation sites relative to sites at lower elevation. Seasonal variation in spring snowmelt can also influence the timing of breeding activity at specific sites since boreal toad breeding in the Rocky Mountains typically begins when snow melts or ice thaws at breeding areas. During the 2004 breeding season many ponds in Colorado thawed and had open water earlier than usual due to limited snowfall, but breeding occurred at about the same time as in previous years. The apparent delay possibly was due to continued cold nighttime temperatures (L.J. Livo personal communication 2002). Females deposit eggs in sunny, shallow water near shore from mid-May to mid-July. Hatching occurs between June and September, typically 10 to 14 days after eggs are deposited, depending on water temperature. Female adult boreal toads may disperse from the breeding site immediately after they deposit eggs; males may remain at breeding ponds for about three weeks after mating. Tadpoles are typically present at breeding sites from mid-July to late August, and newly metamorphosed toadlets are present from late-July to late-September. The time to metamorphosis is highly variable and depends on water temperature and site conditions. In the Rocky Mountains, this time probably varies between 6 and 14 weeks (Patla 2001). Over-winter survival of tadpoles has not been documented in Region 2 (Fetkavitch and Livo 1998).

Breeding behavior

Congregations of adult toads form at breeding sites, where male boreal toads greatly outnumber females. Males typically arrive at breeding sites about five days earlier than females. Male boreal toads do not have an obvious breeding call because they lack the inflatable vocal sac found in many other male amphibians. However, they are known to produce small “chirps”, which are most likely a release call that is made when disturbed by another toad. These vocalizations may also function in the formation of male aggregations at breeding sites and in attracting females (Awbrey 1972). Groups of male boreal toads may sometimes form aggregations whose chirping can be heard from as far as 25 m away (Campbell 1970).

Males in these breeding aggregations may also attempt to amplex other male toads, resulting in a chirping protest response (Black and Brunson 1971, Marco et al. 1998). In some boreal toad populations, this call may be used as an actual mating call and not just a release call (L.J. Livo personal communication 2002). Male boreal toads amplex females in shallow water (<20 cm), and eggs are deposited and fertilized, usually within 6 m of shore, in marshy areas with emergent sedges or shrubby willows, or even bare substrate (Patla 2001). Amplexis lasts until all eggs are deposited. Male boreal toads may amplex more than one female during a breeding season. Adult toads, especially females, usually disperse soon after mating.

Boreal toads show no parental care at breeding sites; in fact, it is common to find almost no adults present near hatch sites by mid-summer. Tadpoles may aggregate in small clumps or in massive groupings that extend several meters across shallow water, especially on sunny days prior to metamorphosis (Koch and Peterson 1995). Such aggregations can result in locally high predation rates. In riverine situations, tadpoles have also been observed being washed downstream of the egg deposition site. Relatively small amounts of current can overcome the ability of tadpoles to remain in the breeding areas where they developed.

Fecundity and survivorship

In the context of this section, the life history stages are defined as follows: egg refers to fertilized eggs, larva refers to tadpoles after hatching until metamorphosis, juvenile refers to new metamorphs up to two years of age, and adult refers to breeding adults greater than two years old. Female boreal toads typically lay 3,000 to 11,000 eggs in a single clutch, and they may breed only every other year. This range in clutch size is typical across the boreal toad range in Colorado. However, there is some evidence that suggests that the number of eggs per clutch may vary widely across the range of boreal toads in Region 2 (Livo 1999). As in many other amphibian species, mortality is very high among egg, larval, and juvenile stages, so actual recruitment to the population is significantly less than what the number of eggs would indicate. Nussbaum et al. (1983) estimated that the mortality rate between egg deposition and the adult stage was 99 percent. Mortality rates among adult boreal toads have not been documented in Region 2, but it is believed to be very low when the chytrid fungus *Batrachochytrium dendrobatidis* is not present. Boreal toads that survive to adulthood, and live where *B. dendrobatidis* is not present, may live nine years or more (Campbell 1970).

Population demography

There is currently very little information available on the demography of boreal toad populations in Region 2 that can be used to predict population trends or responses to threats, or to evaluate the potential of re-introduction efforts. Existing demographic information is largely inferred from size classes observed at breeding sites in Colorado.

With what we currently know, it appears that boreal toads produce large numbers of eggs, have initially high mortality (i.e., during egg, larval, and juvenile stages), develop slowly to maturity, and those that reach adulthood have relatively long lives. Adult females likely do not breed every year in the Rocky Mountains, but they are extremely fecund and may produce as many as 12,000 eggs per clutch (Hammerson 1999). However, the mortality rate between egg deposition and adult live stage can be as high as 99 percent (Nussbaum et al. 1983). Bartelt (2000) observed that it was common for early desiccation of wetlands to destroy the entire reproductive effort of a population, and this severe loss might occur for several years in succession. In the Front Range of Colorado, Campbell (1970) documented that most of the observed mortalities occurred during larval and juvenile stages, and most of the deaths were caused by changes in weather, such as drought causing ponds to dry up before metamorphosis or early freezes killing juveniles. Campbell (1970) also reports predation as a common cause of mortality for juveniles. Boreal toads in Colorado breed for the first time at a minimum age of 6 years for females and 4 years for males (Carey 1976, Hammerson 1999). Boreal toads appear to be long-lived, but precise estimates of maximum age are not available for wild populations. Skeletochronology studies indicate that the maximum life span of boreal toads in Region 2 may be 12 years (Loeffler 2001).

The implication of these demographics is that changes in survival of young (i.e., eggs, larvae, juveniles) can have enormous impacts on abundance within a population, and maintaining stable adult survival is critical to preventing population extinction. Matrix-based life cycle analyses confirm this ([Appendix A](#)). This model suggests that boreal toad populations are sensitive to changes in first year survival, based on both sensitivity and elasticity analyses (see [Appendix A](#) for explanation of terms). The elasticity analysis further suggests that survival of pre-reproductive females is important (i.e., age-classes 2 to 5). In other words, it appears that factors that decrease survival to first reproduction can substantially impact boreal toad populations. This suggests that the

best way to increase the number of large, fertile females (the mainstay of a healthy population) is by increasing the survival rates of earlier age classes. Further, when stochasticity is introduced to the models, populations of boreal toads appear relatively tolerant to fluctuations in egg production (due, for example, to annual climatic change or to human disturbance), but they are extremely vulnerable to variations in the survival of adult stages. This is not meant to suggest why populations might be declining; there may be entirely external reasons, such as destruction of breeding habitat. It merely suggests which transitions in the boreal toad life cycle are most likely to have a strong effect on population dynamics.

The BTRT has plans to conduct Population Viability Analyses in order to determine an estimated genetic and demographic minimum viable population and to create an integrated model to predict the viability of specific populations. This work is ongoing, but preliminary results from research at Colorado State University have not been released (R. Sherer personal communication 2003). However, given the uncertainty surrounding demographic parameters, it is unlikely that such an effort will produce results that will substantially alter existing management recommendations.

Genetic concerns

The boreal toad is a subspecies of the western toad complex that is found throughout western North America. The SRMP, which ranges from southeastern Wyoming to northern New Mexico, is geographically isolated from populations in western North America by dry, non-forested intermountain valleys. Evidence suggests that the SRMP of boreal toads in Region 2 is genetically differentiated and probably represents an independently evolving lineage or species (Goebel 1996). This isolation is a concern since this population has experienced dramatic recent declines and there is no source for a natural rescue effect from adjacent populations. There is a possibility that the distinct genetic characteristics and the fitness for habitats in the range of the SRMP may be lost if this population is extirpated. Initial tests indicated that boreal toads in Utah are closely related to toads in the SRMP. Recent analysis of mtDNA and nDNA from boreal toads in Utah, Idaho, Wyoming, and Colorado indicates that boreal toads in Utah and Idaho are genetically distinct from toads in the SRMP. Boreal toads in Sublette County, Wyoming, which have been classified as Northern Rocky Mountain boreal toads, may be more closely related to toads in the SRMP. Additional data are needed to confirm these hypotheses, and specimens

collected from western Wyoming can be used to help determine the genetic relationship of these boreal toads to the SRMP.

Metapopulations

Little research specifically addresses metapopulation dynamics in boreal toads. However, there are many examples where habitat changes or direct anthropogenic and natural factors have resulted in the loss of local amphibian populations (Bury et al. 1980, Rosen et al. 1995, Lind et al. 1996, Beebee 1997). The loss of local populations may influence the persistence of regional populations or metapopulations, even in cases where habitat quantity remains constant (Hanski and Gilpin 1991, Robinson et al. 1992, Simberloff 1993, Fahrig and Merriam 1994). Research in Arizona documented that the extirpation of native amphibians due to the introduction of non-indigenous species led to the extirpation of native amphibians from nearby areas when the smaller wetlands into which the native species were forced dried up during a drought (Rosen et al. 1995). This example illustrates how the loss of core habitat that supports a local source population can lead to widespread extirpations within a metapopulation.

Habitat characteristics, such as patch size, shape, isolation, and quality, strongly influence the persistence of regional amphibian metapopulations. The size of a habitat patch is directly related to the probability that the patch is occupied by amphibian species (Laan and Verboom 1990, Marsh and Pearman 1997, Fahrig 1998). The distribution of patches across the landscape also influences whether a patch is occupied. Additionally, the degree of isolation is often negatively related with patch occupancy (Sjögren 1991, Vos and Stumpel 1995, Sjögren-Gulve and Ray 1996). Changes in the habitat matrix between patches can also affect occupancy as illustrated by the example of Sjögren-Gulve and Ray (1996) in which they found that drainage ditches between ponds created a barrier that isolated the populations in adjacent ponds.

A key element in understanding the dynamics of boreal toad metapopulations is the maximum dispersal and migration distances of toads in local populations, which we have discussed earlier in the “Activity and movement patterns” section. This information is unknown for many areas, and it could be highly variable depending on the composition of habitats in different regions occupied by boreal toads. Radio-telemetry studies of boreal toad movement and habitat use, such as the research conducted by Bartelt (2000), would be very helpful in gathering this information.

Community ecology

Community ecology attempts to describe the interactions of a given species within the greater ecosystem to which it belongs. This obviously includes such factors as habitat and food habits, which were described in previous sections, but it also includes predation, competition, parasitism, disease, and symbiosis, which are summarized in the following paragraphs

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 to proximate 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 boreal toads (**Figure 13**), which represents a basic framework for the possible web of ecological relationships linked to the boreal toad. 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 boreal toad populations across Region 2 in a variety of situations. It should be viewed as a quick reference, highlighting some key linkages in the community ecology of the boreal toad, but by no means does it define this environment.

Natural predators of the boreal toad include, but are not restricted to the following (see Arnold and Wassersug 1978, Beiswenger 1981, Corn 1993, Hammerson 1982, Jennings et al. 1992, Jones and Goettl 1999, Livo 1999, Long 1964, Olson 1989): common ravens (*Corvus corax*), gray jays (*Perisoreus canadensis*), robins (*Turdus migratorius*), spotted sandpipers (*Actitis macularia*), red-tailed hawks (*Buteo jamaicensis*), western garter snakes (*Thamnophis elegant*), tiger salamanders (*Ambystoma tigrinum*), badgers (*Taxidea taxus*), red fox (*Vulpes vulpes*), raccoons (*Procyon lotor*), and predaceous diving beetle larvae (*Dytiscus* spp.), which only prey on boreal toad larvae. There is little evidence to indicate that predation

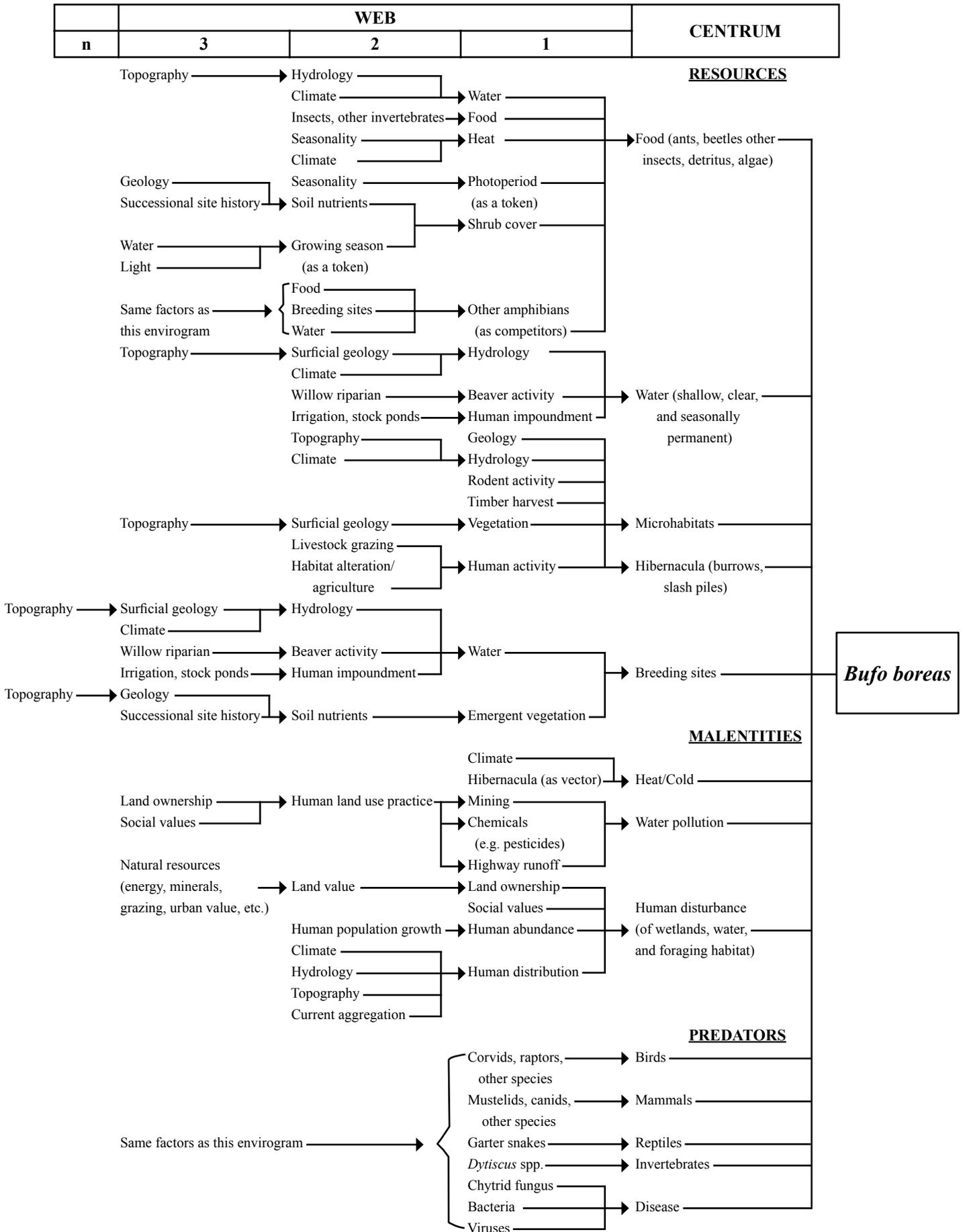


Figure 13. Envirogram for all life history stages of the boreal toad.

is a factor that causes population declines in boreal toads; at most, predation is a minor contributing factor to observed population declines.

Introduction of game fish to historically fishless waters has reduced many amphibian populations throughout western North America (Bradford 1989, Bradford et al. 1993, Corn 1994), but there is no direct evidence that this has contributed to the decline of boreal toads. Boreal toad eggs and tadpoles are toxic or distasteful to most predators (Licht 1969, Brodie and Formanowicz 1987, Hews 1988), and although this does not render them immune to predation, there are several current and former boreal toad-breeding sites that also contain fish.

Boreal toads are susceptible to a variety of bacterial and fungal pathogens that have been documented in Region 2, but the primary disease-causing pathogen is a specific form of the chytrid fungus *Batrachochytrium dendrobatidis*. More broadly, chytrid fungi have caused mass mortality of amphibians in Arizona, California, Colorado, Wyoming, Central and South America, and Australia (Daszak et al. 1999, Parker 2000). The frog chytrid is a microscopic, parasitic fungus that attacks the keratin and skin of amphibians and has caused 90 to 100 percent mortality rates in metamorphosed amphibians. Amphibian larvae are not lethally affected by chytrid because only their mouthparts contain keratin. However, boreal toad tadpoles may carry this disease and die from it after metamorphosis, or in some cases they may rid themselves of the chytrid infection during metamorphosis (L.J. Livo personal communication 2002). This fungus represents a substantial challenge for boreal toad conservation, as discussed in “Extrinsic threats” section below.

Boreal toad symbiotic relationships fall into two main types: those that are commensalistic and those that are parasitic. The many pathogens that affect toads are considered parasitic (see above). On the other hand, beaver have a commensal relationship to boreal toads, because they modify wetlands and create ponds that can improve the quantity and quality of breeding habitat available for boreal toads in mountain streams, but beaver do not appear to benefit from the presence of toads. A number of small mammal species also have a commensal relationship with the boreal toad. The small mammals create burrows that provide important over-wintering habitat for boreal toads to use as hibernacula, but they do not appear to benefit directly from the toads.

CONSERVATION OF BOREAL TOADS

Threats

The status of boreal toads from the NRMP within Region 2 national forests is comparatively unknown. Therefore, the information on the conservation status of the boreal toad discussed below focuses on the SRMP.

Extrinsic threats

As discussed above, both the distribution and abundance of boreal toads have substantially declined throughout their range in Region 2 (see “Range, distribution, and distribution trends” and “Abundance and population trends” sections). A combination of the threats discussed below is likely causing these declines by making formerly suitable habitat unable to support breeding toads; no single factor has been identified as the primary threat to boreal toad habitat. Unfortunately, information on the general trend of boreal toad habitats in terms of either habitat quality or distribution is limited. There is evidence suggesting that the chytrid fungus *Batrachochytrium dendrobatidis* is, perhaps, the most pervasive factor decreasing habitat quality at the range-wide scale. Although this pathogen can have devastating impacts, it is still only one contributing factor in any given case, so managers should not focus on it to the exclusion of other concerns. It is possible that any resource management that negatively affects mountain wetlands or ponds will also negatively affect breeding habitats for boreal toads. Moreover, the relative importance of any threat depends on the locality in question. In the mountains of Colorado and southeastern Wyoming, habitat alteration could also be a large factor; but no studies have investigated the relationship of habitat and population trends in areas where declines have been observed. Such studies would be difficult to conduct since there is no baseline to suggest what habitat parameters were for most of these sites prior to the decline of boreal toads. Establishing a current baseline of both toad population status and habitat quality parameters and monitoring changes at known breeding sites are essential for determining habitat trends in boreal toad range within Region 2.

Specific threats to boreal toads on Region 2 National Forest System lands include disease, decreased water and air quality, timber harvest, livestock grazing, fire and fire management activities, environmental pollutants, non-native species and their management,

habitat development and fragmentation, harvest and commerce, and finally the lack of information on specific populations.

Disease

Several diseases have been identified in boreal toads, but that of primary concern appears to be chytridiomycosis, which stems from infection by the chytrid fungus *Batrachochytrium dendrobatidis* (BD). This disease has been linked to declines in amphibian populations in Australia, Central America, North America and Europe (Berger et al. 1998, Carey et al. 1999, Daszak et al. 2000a, Bosch et al 2001). Daszak et al. (2000a) note that it has changed how people think about Emerging Infectious Diseases in wildlife, because it emerged with comparative synchrony throughout the world in both disturbed and “pristine” environments, thus making a causative reason for its emergence very difficult to find. We only know that it can cause drastic mortality in populations of susceptible amphibians. There is still no answer to why the disease is suddenly impacting certain amphibians, including the boreal toad. Below we have summarized some formative hypotheses, and we mention their management implications in the “Implications of conservation elements” section.

Carey (2000) hypothesizes that BD is responsible for the historical declines in boreal toads that began in the 1970s in Colorado and more recent declines in remaining Colorado boreal toad populations, and has further been a factor limiting their recovery (Carey et al. 2002). Recent modeling research on boreal toad populations in Rocky Mountain National Park by R. Scherer (unpublished 2002) at Colorado State University indicates that the observed declines fit very closely with a model of population changes following introduction of BD. Die-offs from BD may take place gradually, over weeks or months, making them difficult to detect unless frequent surveys are conducted for dead amphibians. In many cases, die-offs from BD are also difficult to detect because most deaths are not observed (Livo and Jones 2000). Populations of boreal toads infected with BD have declined to near extinction within one year, and there are no documented cases of an infected population recovering. However, ongoing research suggests that some toads show an ability to survive infection if they are able to stay dry, warm, and bask regularly (L. J. Livo, unpublished data). This information, however, is far from conclusive and does not yet suggest any new avenues for conservation. The fact remains that the vast majority of toad populations are severely impacted when infected by BD.

Questions remain as to why BD has recently emerged as such a dramatic threat and what we can do to counter its devastating effects. Carey (1999) hypothesized that BD is so detrimental to boreal toad populations because it is a recently emerged infectious disease to which toads have not evolved resistance. This theory is supported by genetic research on chytrid fungi that shows globally low variation, presumably due to the fact that it spread very recently (Collins and Storfer 2003). There is evidence from museum specimens that BD was indeed present during the initial population declines (L.J. Livo personal communication 2002), but there is no evidence that it occurred in wild populations prior to human contact; so its origin remains unclear.

Cary (1999) also suggests that environmental stress is making toads more vulnerable to infection. This idea has been put forth by other scientists for a variety of amphibians, with hypothesized stressors including global climate change and local imbalances in water chemistry due to acidification, chemical contamination, or changes in water temperature (e.g., Pounds et al. 1999, Collins and Storfer 2003). However, some researchers believe that no environmental stress is needed to make toads vulnerable to infection by BD; it can be just as deadly under ideal environmental conditions. This is supported by evidence from other amphibians where no other environmental abnormalities were detected (i.e., a stable pH, no pollutants, no habitat disturbance, no unusual weather, no increased UV radiation; Berger and Speare 1998), and by studies showing little correlation between declines and weather patterns (Alexander and Eischeid 2001, Carey and Alexander 2003).

Lately, some scientists have suggested that there may be life history traits that predispose certain amphibians to be susceptible to chytridiomycosis. According to Daszak et al. (2000a), declining populations appear to be niche specialists, to have lower than average fecundity, and/or to live in cool climates that favor development of the fungus. Other reports suggest that epizootics are most common at higher elevations (at least in the tropics) and that the species most affected tend to breed in streams, have restricted elevational ranges, and have a large body size (Collins and Storfer 2003). Boreal toads meet all of these criteria.

Other pathogens cultured from dead boreal toads include the bacteria *Aeromonas hydrophila* and the fungus *Basidiobolus ranarum*. While these may cause death in boreal toads, recent analysis of infected toad specimens indicates that toads from which *B. ranarum*

was cultured were actually killed by BD (Pessier 2002). A recently identified condition among captive-bred boreal toads, called “edema syndrome,” may be a new bacterial infection (Loeffler 2001). However, researchers at the Native Aquatic Species Restoration Facility in Colorado have not yet identified the cause of this condition (Scherff-Norris et al. in prep).

Water and air quality

Acidification of wetlands may be a cause of developmental abnormalities and increased mortality of boreal toads during the embryonic and larval history stages (Porter and Hakanson 1976, Corn et al. 1989, Vertucci and Corn 1996). Research on the direct effects of acid deposition on boreal toads in the Rocky Mountains indicates that the current levels of acidification are not a significant problem for boreal toads. Laboratory studies indicate that pH levels of 4.4 to 4.5 result in 50 percent mortality of boreal toad embryos. Breeding habitats of boreal toads in the Rocky Mountains rarely have pH levels less than 6.0. Here again, effects other than direct mortality were not investigated.

The low acid-neutralizing capacity of water at boreal toad breeding sites indicates that about half of the known breeding areas are sensitive to damage from acidification. Sulfate deposition rates greater than 10 kg per hectare per year may reduce the acid-neutralizing capacity of the water in these breeding sites to the point where pH levels become more acidic. When pH levels drop below 6.0, changes in algal communities that would affect the growth and development of boreal toad tadpoles can occur (Corn and Vertucci 1992).

Acidification of aquatic habitats and deposition of heavy metals from mine tailings may make historical breeding sites inhospitable for boreal toads. However, an evaluation of acidic deposition in the Rocky Mountains indicates that the current magnitude and distribution of the problem is not significant enough to be a primary factor in the range-wide decline of the boreal toad (Corn and Vertucci 1992, Vertucci and Corn 1996).

Researchers have also investigated the effects on boreal toads of increased UV-B radiation due to thinning of the atmospheric ozone layer. Results indicate that ambient UV radiation does not have direct lethal effects on any life history stage of boreal toads in the Rocky Mountains (Corn 1998). However, in Oregon, ambient levels of UV radiation have caused increased mortality of boreal toad embryos (Blaustein et al. 1994) by causing them to become susceptible to a formerly innocuous microorganism. Because research has focused only

on direct mortality and not indirect or synergistic effects, the BTRT has not dismissed the possibility that increased levels of UV radiation are a contributing factor in recently observed declines of boreal toads in the Rocky Mountains. For instance, Carey (1993) hypothesized that heavy metals and UV radiation may act synergistically with other environmental stressors and depress the immune system of boreal toads, making them vulnerable to infection and death from pathogens. This, however, is a difficult thing to prove, and research has yielded very few insights (see “Disease” section). All else being equal, however, it makes sense that added stressors serve only to decrease the viability of a population. Therefore, until research defines a clear priority, the goal of land managers should be to assign equal (and high) priority to eliminating all factors that have been shown to be detrimental to boreal toads.

Timber harvest

The impact of timber harvest on boreal toads depends greatly on the timing, method, spatial extent, configuration, and location of harvest activities relative to boreal toad habitats (Maxell 2000). A thorough review of forest management practices and their effects on amphibian ecology can be found in deMaynadier and Hunter (1995). In general, boreal toads appear to be less vulnerable to habitat changes that follow timber harvests than other amphibian species; however, harvests can still impact populations and negatively affect toad habitat. Direct effects from timber sales include mortality of toads crushed by equipment used during harvest activities. Boreal toads may be particularly vulnerable to impacts of timber harvesting when harvest activities occur within their dispersal range from breeding sites, and during the late summer when adults migrate into upland forested habitats (**Table 3**). In 18 studies reviewed by deMaynadier and Hunter (1995), they found that frogs and toads were less abundant on six-month to 40-year old clearcuts, as compared to uncut control plots.

Disturbance of stream habitats from sedimentation is one of the greatest impacts of timber harvest on amphibian species. Timber harvest activities typically include the development and maintenance of roads, which may further increase erosion and sedimentation in adjacent streams and wetlands. These impacts can affect boreal toads most significantly during the larval stage, when they are limited to aquatic habitats. Clearcuts may influence boreal toad use of migration corridors due to the decreased moisture and increased heat within the clearcut (Bartelt 2000). Tree removal may enhance or reduce the structure and composition

Table 3. Crucial periods in the life cycle of the boreal toad.

Period	Events	Timing
Breeding Period	Breeding begins 2 to 4 weeks after appearance of open water	Mid-May to mid-June (July at higher elevations)
Hatching	Eggs hatch 1 to 2 weeks after being laid	Late May to late June (late July at higher elevation)
Metamorphosis	Tadpoles metamorphose to toadlets in approximately 2 months	Late July to late August (late September at higher elevation)
Toadlet Dispersal	Toadlets leave natal area	Highly variable
Overwintering	Adults and juveniles occupy winter habitat	Late September to mid-May

of shrub understories. Shrub understories provide important microhabitats that aid in thermoregulation by providing water and heat energy for boreal toads (Bartelt 2000). Soil compaction from harvesting activities may reduce the availability of rodent burrows used by boreal toads as over-wintering hibernacula (Loeffler 2001). In some cases, timber harvesting can benefit boreal toads by increasing small mammal habitat and thus available burrow habitat. Boreal toads may over-winter in these burrows and in slash piles (Bartelt 2000). In general, though, any timber harvest activities that negatively affect the quality or quantity of wetlands within the current range of boreal toads can be harmful to this species.

Livestock grazing

Riparian areas provide critical breeding, foraging, and over-wintering habitats for boreal toads, and they are used as dispersal corridors for juvenile toads. Given the access to water and the typically richer vegetation, these habitats are also preferred areas for livestock grazing, which has been associated with a wide range of negative impacts on habitat and vertebrate taxa (Fleischner 1994). Bartelt (1998, 2000) observed that livestock activity in and around a breeding pond on the Targhee National Forest caused significant mortality for boreal toads from trampling and microhabitat disturbance. Thousands of boreal toad metamorphs were killed when sheep were herded through a drying pond where the toads were concentrated; hundreds of the toads were directly killed by trampling, and hundreds more died afterward from desiccation because the vegetation they had been using for cover was trampled to the point that it no longer provided moist microhabitats (Bartelt 1998, 2000).

Livestock grazing may have several indirect effects on boreal toads at all life history stages. The survival of tadpoles and eggs can be reduced from decreased oxygen levels in heavily used watering holes, hydrologic changes due to stock pond development,

predation due to loss of cover, and poisoning due to fecal contamination of wetlands. Livestock grazing may also reduce the number of insect prey upon which amphibians depend (Fleischner 1994). Prairie dog and other rodent control programs associated with the protection of livestock from injury may reduce the number of burrows available for winter hibernation (Sharps and Uresk 1990). Compaction of soils in riparian areas may eliminate the ability for amphibians to burrow underground in order to prevent desiccation or freezing (Duellman and Trueb 1986, Swanson et al. 1996). Long-term effects of livestock grazing may include degradation of riparian and wetland areas due to 1) decreased stream bank storage, which maintains stream flow during droughts, and 2) decreased riparian vegetation, which filters water and provides microhabitats that are important for thermoregulation. Loss of bankside willows may also result in reduced beaver activity or extirpation of beavers, a species whose activities are responsible for the creation of amphibian breeding habitats (Donkor and Fryxell 1999, Russell et al. 1999a).

Fire and fire management activities

Despite the lack of research on fire and amphibians, wildfire, prescribed fire, and fire control actions are likely to have direct and indirect effects on boreal toads (Maxell 2000). Due to their slow locomotion, amphibians have a relatively low ability to escape fire, especially in a forest environment; therefore, they may face high rates of mortality during fires (Friend 1993, Russell et al. 1999b, Papp and Papp 2000). Vogl (1973) reported direct mortality of amphibians from fire in wetlands in the southeastern United States. Increased sedimentation in streams due to post-fire erosion may reduce the number of shallow pools and backwaters that provide breeding habitat for adults and feeding areas for larvae. Fire may also remove vegetation and structures that provide microhabitats that amphibians use for thermoregulation.

Fire is a natural event through which boreal toads have historically survived as a species. Fire suppression may indirectly affect boreal toad habitat by altering the natural succession cycles in forest communities. These changes could have both positive and negative effects on boreal toads and their habitat. Boreal toads may benefit from an increased shrub understory following re-growth after a fire, and they may be affected negatively by the removal of downed woody material, which provide refugia (Bartelt 2000).

Pesticides, herbicides, and environmental contaminants

Both aquatic larval and terrestrial adult life history stages are vulnerable to exposure to toxic chemicals, as their highly vascularized epidermis with little keratinization allows for easy absorption of many chemicals. The reader should consult Saunders (1970) and Harfenist et al. (1989) for a discussion of the lethal toxicity of herbicides and pesticides on amphibians. However, sub-lethal effects resulting from lower levels of exposure are likely far more prevalent and damaging on a distribution-wide basis. Chemical contamination has been documented to cause direct mortality, depressed disease resistance, inhibition of growth and development, decreased reproduction, inhibition of predator avoidance behaviors, and morphological abnormalities (Cooke 1981, Hall and Henry 1992, Boyer and Grue 1995, Carey and Bryant 1995, Sparling et al. 2000). Other noted sublethal effects include decreased thermal tolerance (Johnson and Prine 1976), decreased corticosterone production and inhibited gluconeogenesis (Gendron et al. 1997), decreased growth rate and inhibition of predator response (Berrill et al. 1993, Berrill et al. 1994). Further, many chemicals may persist in amphibian habitats and have detrimental effects long after they were used. Russel et al. (1995) detected toxic levels of DDT in tissues of spring peepers (*Pseudacris crucifer*) at Point Pelee National Park, Ontario even though DDT had not been used in the area for 26 years.

Boreal toad larvae are vulnerable to the use of piscicides in their habitat since they depend on aquatic respiration; adults are less vulnerable since they can escape from treated areas by exiting treated waters. Fontenot et al. (1994) and McCoid and Bettoli (1996) reviewed research that documented substantial mortality of amphibian larvae from piscicide treatments. They also reviewed research on the lethal effects of rotenone-containing piscicides on amphibians. The range of lethal doses of rotenone for amphibian larvae (0.1 to 0.580 mg per L) overlaps with the lethal doses for fish (0.0165

to 0.665 mg per L), and these lethal concentrations are lower than the concentrations commonly used in fisheries management (0.5 to 3.0 mg per L). The effects of rotenone on newly metamorphosed and adult amphibians is highly variable, depending on the degree of each species' aquatic respiration and their likelihood of escaping from treated areas by exiting the water (Fontenot et al. 1994, McCoid and Bettoli 1996). The non-target effects of antimycin have not been formally studied, but observations by Patla (1998) indicate that it is also toxic to amphibian larvae.

Non-indigenous species

There is potential for non-indigenous species to threaten boreal toads either directly through predation or indirectly as competitors for resources, vectors for pathogens, or as a consequence of management actions that target non-indigenous species (e.g., use of piscicides, insecticides, or herbicides).

At least 104 species of fish have been introduced in Colorado and Wyoming (Fuller et al. 1999, Nico and Fuller 1999), and many native fish have been transplanted into drainages where they were historically never present (Baxter and Stone 1995). Introduced fish species have been documented to cause declines of amphibian species worldwide (Sexton and Phillips 1986, Bahls 1992, Bradford et al. 1993, Bronmark and Endenham 1994, Brana et al. 1996, Hecnar and M'Closkey 1997, Fuller et al. 1999). Specifically, introduced salmonids present a significant threat to amphibian communities that occupy high mountain lakes because estimates suggest that 95 percent of these lakes in the western United States were historically fishless prior to the advent of artificial stocking programs (Bahls 1992). Because most of these high mountain lakes would have supported only native amphibian communities, the threat of predation from fish would have been absent and native amphibians would not have evolved mechanisms to cope with predation by fish. Studies suggest that amphibians at all life history stages are vulnerable to predation by introduced fishes (Licht 1969, Semlitsch and Gibbons 1988, Liss and Larson 1991). Further, the presence of predators has been shown to have the following indirect effects on amphibians:

- ❖ adult avoidance of egg laying sites where predators are present (Resetarits and Wilbur 1989, Hopey and Petranka 1994)
- ❖ decreased larval foraging and growth rates as a result of staying in refuges to avoid

predators (Figiel and Semlitsch 1990, Skelly 1992, Kiesecker and Blaustein 1998, Tyler et al. 1998)

- ❖ decreased adult foraging, growth rates, and over-winter survival as a result of avoiding areas with fishes (Bradford 1983).

However, evidence suggests that direct predation from fish may not be a serious threat to boreal toads. Boreal toad adults produce toxic secretions from glands on their skin, particularly the parotid gland behind the eyes, which may provide some defense from predation by fish (Patla 2001). Tadpoles and eggs are likewise thought to be unpalatable to predators (Nussbaum et al. 1983), and there is evidence that salmonids may not routinely prey on boreal toad tadpoles (Jones and Goettl 1999). Given these factors, fish are currently considered a low threat to the survival of boreal toad populations in Region 2 (L.J. Livo personal communication).

The bullfrog (*Rana catesbeiana*) is a non-indigenous species in Colorado and Wyoming, and they have been implicated as a cause of amphibian declines throughout the western United States (Moyle 1973, Hammerson 1982, Bury and Whelan 1984, Kupferberg 1994, Rosen et al. 1995, Kupferberg 1997, Lawler et al. 1999). Amphibians at all life history stages may be vulnerable to predation from adult bullfrogs (Carpenter and Morrison 1973, Bury and Whelan 1984, Clarkson and DeVos 1986), and eggs and larvae may be preyed upon by bullfrog tadpoles (Ehrlich 1979, Kiesecker and Blaustein 1997). However, the ranges of boreal toads and bullfrogs do not usually overlap in Region 2, as bullfrogs typically occupy low elevation habitats and boreal toads are often restricted to higher elevations. Nonetheless, bullfrogs are frequently transplanted by humans into new areas and therefore could present a threat to some boreal toad populations if established in occupied boreal toad habitat.

Perhaps a bigger threat to boreal toads is the introduction of exotic pathogens. Introduced fishes and non-indigenous species, such as bullfrogs and other amphibians sold at pet stores, may act as vectors for pathogens that infect amphibians. Chytrid fungus is hypothesized to be the primary cause of amphibian declines in Australia, Central America, and the western United States, and many amphibians exported to United States pet stores come from the areas where chytrid fungus was first documented during dramatic amphibian declines (Daszak et al. 1999, 2000a, 2000b). Blaustein et al. (1994) observed that the water fungus *Saprolegnia*, a common pathogen of fish species reared and released

from fish hatcheries, has also been associated with amphibian declines. This suggests that releasing hatchery-raised fish into the wild may increase the risk of infecting amphibians with pathogens from fish. Additionally, pathogens introduced by non-indigenous species are suspected to act synergistically with other natural and anthropogenic-caused threats. Kiesecker and Blaustein (1995) observed that the combination of UV radiation and *Saprolegnia* fungus increased occurrences of mortality in amphibian embryos.

There is relatively little information on the impact of exotic weeds on amphibians. However, there is some evidence that the presence of exotic aquatic vegetation enhances the survival of non-indigenous bullfrogs (Kupferberg 1996, 1997). Management of weed and insect pests with chemical herbicides and pesticides can be a significant threat to amphibians (see above section).

Habitat development and fragmentation

Many of the factors described above may result in the loss or fragmentation of boreal toad habitat and the subsequent loss of local populations. A detailed understanding of the effects of habitat fragmentation on metapopulation dynamics of boreal toads is needed to effectively evaluate how it threatens specific populations of boreal toads in Region 2. Habitat patch size, shape, isolation, and quality could all be important characteristics that influence the persistence of local metapopulations of boreal toads. In general, any activities that alter mountain wetland habitats could potentially affect the persistence of boreal toads in these areas (Loeffler 2001).

Roads and trails in boreal toad habitats and migration corridors are a direct threat to the species. Amphibians are particularly vulnerable to vehicular collisions during migrations across roads to and from breeding habitats (Turner 1955). In some studies, this source of mortality has caused substantial impacts on the population level of amphibians (Lehtinen et al. 1999).

Recreational developments that disturb wetland habitats may cause direct mortality of amphibians from construction equipment and vehicles. Amphibians in or near recreational facilities are also at risk of mortality because of handling by humans (Reinking et al. 1980) and killing by human pets (Coman and Brunner 1972).

The development and management of water impoundments can significantly alter amphibian habitats and may negatively affect populations

by causing breeding areas to dry up before larvae metamorphose. Additionally, if water bodies are made more permanent, then they may attract predators that negatively impact amphibian populations (Campbell 1970, Skelly 1992, Koch and Peterson 1995, Scott 1996). In some cases, the replacement of ephemeral wetlands with developed water impoundments has resulted in the loss of critical habitats for amphibians. For example, the Jordanelle Reservoir on the Provo River in Utah flooded large amounts of ephemeral wetland habitats used by Columbia spotted frogs (*Rana luteiventris*) (Wilkinson 1996).

Harvest and commerce

Worldwide, the collection and harvest of amphibians for commercial use is extensive, and an estimated hundreds of millions of amphibians are collected and/or killed every year (Pough et al. 1998). Currently there is no information on the extent to which boreal toads in Region 2 are collected or harvested for biological or commercial purposes.

Intrinsic vulnerability

In addition to the threats discussed above, several aspects of boreal toad biology make them particularly susceptible to population declines, and managers should consider these intrinsic threats when developing conservation strategies. Boreal toads are intrinsically more vulnerable to disturbance because they have low reproductive output, restrictive habitat specificity, and susceptibility to disease.

Low reproductive output

Females do not begin breeding until they are six years old, probably only breed every other year, and are not likely to live much beyond nine years. This means that a single female may only produce two or three clutches of eggs in her lifetime. Further, although these clutches may be large (e.g., thousands of eggs per clutch), very few of those eggs are likely to reach breeding age. Mortality may be as high as 99 percent for larval and metamorph life history stages, and in many case it may be up to 100 percent. Once toads have survived their first year, mortality rates decline. Therefore, the link most directly affecting the population's ability to rebound from a crash, as suggested by the matrix life cycle analysis (**Appendix A**), is survival through the first year of life (i.e., from egg to tadpole to metamorphosis through hibernation to spring emergence). However, the survival of adult toads is most critical to a population being able to withstand

short-duration variability, because they are the "reservoir" through which the population is re-seeded.

Therefore, (in the absence of outside influences) populations are more likely to grow if survival of young stages can be increased, and a stable crop of adults is necessary for long-term persistence in a variable environment. This is a huge hurdle, because it depends on a multitude of factors unique to the amphibian life cycle. Eggs and tadpoles depend on aquatic conditions, metamorphs depend on both aquatic and terrestrial conditions, and juvenile and adult toads depend on suitable upland habitat and hibernacula. This is compounded by the fact that, as described above, the reproductive window for boreal toads is very narrow. This implies that only a few successive mortality events among pre-reproductive toads may effectively cause a population to crash, whereas a species that produced more clutches in its lifetime would better be able to recover from a few years of poor recruitment.

Restrictive habitat specificity

Boreal toads depend on both aquatic and terrestrial habitats for reproduction, foraging, and overwintering. Thus, they are vulnerable to changes in both of these habitats. Additionally, the necessity for the juxtaposition of suitable wetland and terrestrial habitats restricts the amount of available habitat overall.

Susceptibility to disease

Boreal toads are susceptible to pathogens that can result in high mortalities (see "Disease" section). In particular, BD poses a serious threat at both the level of the individual population and across the species' range. Mortality rates in infected populations have approached 90 to 100 percent in many cases (Patla 2001), and the fungus is continually being documented in new areas. For instance, the first case of BD in the NRMP on the National Elk Refuge was discovered in 2000 (Patla 2000b), which means that the geological divide between the SRMP and the NRMP is not a barrier to the spread of the disease.

Management of Boreal Toads in Region 2

Implications and conservation elements

In order to ensure the survival of boreal toads in Region 2, local management plans must assess the impact of the threats identified above at both the landscape and individual population scales. It is the

authors' opinion that identifying and conserving specific breeding populations that are free from BD infection is the most effective method for conserving boreal toads in the Rocky Mountain Region.

The following information reiterates how changes in the environment may affect the abundance and distribution of boreal toads in Region 2 and outlines specific conservation actions that can help to conserve boreal toads. It focuses on identifying desirable future conditions for boreal toad habitat relative to identified threats and listing priorities to achieve these desired conditions. These management approaches have either been implemented or proposed for the conservation of boreal toads, or they are suggested by scientific research. This section is not a recipe for management action by the USFS in Region 2; rather it suggests potential options based on our best knowledge of this species and threats to its survival (Loeffler 2001).

Disease management

As noted earlier, it is clear that chytridiomycosis is an important factor in boreal toad declines, but there is still no clear understanding of the reason for the sudden and widespread impact of this disease on boreal toad populations. Further, there is currently no test to determine if the BD is present in boreal toad habitats without a sample from an infected amphibian; this is why so many sites have yet to be tested (**Table 2**). Pisces Molecular LLC, in cooperation with the BTRT, is trying to develop a real-time PCR assay that would serve this function (Boreal Toad Recovery Team 2003), but it is unknown when (or if) such a test will be applicable in the field.

Once we know which sites contain BD, the nature of the disease will, in part, determine the best course of action. If the disease is an invasive that human action has helped to spread, the primary solution must be to stop its spread and then find a way to recover infected populations. However, controlling disease in wildlife is very problematic, particularly when there is no easily identifiable reservoir for its spread. Therefore, it may be more logical to determine why some populations are able to persist in the presence of BD while others crash and/or go extinct. We can then apply this knowledge to prioritize conservation efforts. For example:

- ❖ If newly evolved environmental stressors (e.g., increased UV radiation, chemical contamination, decreased water quality, human disturbance) facilitate infection, then management should focus on

eliminating those stressors from boreal toad habitats, thus enabling the remaining boreal toads to recover and repopulate their former range.

- ❖ If certain habitat characteristics (e.g., elevation, water temperature, vegetative cover) mitigate the rate of infection or the mortality rate of those infected, then sites with those characteristics should be given conservation priority. Further, habitat manipulation that promotes those characteristics could be implemented in other sites, especially those that have not already been infected.
- ❖ If some toads exhibit natural resistance to infection, then those animals should be the focal point of captive breeding and reintroduction programs.

Regardless of the nature of BD, it is evident that other threats will only serve to compound the impact of the disease, particularly habitat alteration and destruction that isolates population segments. Therefore, it is crucial that habitat preservation efforts not be overlooked in favor of disease research.

Determine population status

The distribution and location of active breeding populations must be determined within Region 2 for both the SRMP and the NRMP of boreal toads (see "Inventory and monitoring" section). There are extensive areas within Region 2 that have not been adequately surveyed in order to obtain up-to-date, accurate information on the abundance and distribution of boreal toads.

Monitor known populations

Known breeding populations must be monitored to track changes in abundance and behavior and to evaluate impacts of management actions (see "Inventory and monitoring" section). Further, given the importance of disease as a controlling factor in boreal toad populations, it is very important that populations be monitored for BD infections.

Delineate important habitat

Having inventoried boreal toad populations, managers should identify important terrestrial habitats (i.e., foraging areas, over-wintering sites,

and movement corridors) and aquatic habitats (i.e., permanent ponds and river and stream habitats within 2.5 km of known breeding ponds). Managers should then assign priorities for protecting and monitoring boreal toad habitats, wherein the healthiest populations receive greater priority.

Protect suitable habitat

To insure population persistence, important habitat must be protected from natural and human-caused disturbances that could potentially threaten the survival of boreal toads at the local, population, and/or landscape scale. This includes not only the breeding sites, but also the network of upland habitat and migration corridors. Habitats with BD-free populations should receive high priority for protection.

Tools and practices

Population and habitat management

The key element in any management of boreal toad populations or habitats is to develop an efficient method to test for and treat BD in both infected toads and their habitats. Following this, it will be necessary to manage boreal toad habitats in order to minimize the effects of the threats identified earlier in this assessment. In the *Boreal Toad Conservation Plan and Agreement*, the BTRT details several key elements in their habitat management strategies that adequately address these threats (Loeffler 2001); these are outlined below.

Pre-management surveys: Habitats that may be suitable for breeding, foraging, over-wintering, or migration by boreal toads should be surveyed prior to any management activity that could impact the toads or their habitat. If the loss or deterioration of boreal toad habitat is inevitable, then mitigation measures should be implemented.

Water and air quality: Acidification of aquatic habitat from air pollution is a factor that threatens amphibians, specifically during the embryonic stage. This type of acidification is a wide-ranging problem, and pollution from relatively distant sources can influence acidification in Region 2. Areas in the Park Range in northern Colorado currently have acid deposition levels sufficient to cause chronic acidification and to damage aquatic habitats used by boreal toads. To provide boreal toads a buffer to known detrimental levels of 10 kg per ha per year (see Threats), it is the opinion of the authors that regional levels of sulfate deposition

should not exceed 6 kg per ha per year in areas known to support boreal toads. Hardrock mining can also produce acid water and sediments that are transported by groundwater. Effluent from such mines should be monitored to insure it is not impacting the pH of water in hydrologically connected wetlands occupied by boreal toads.

Further, heavy metals and other contaminants from mine sites may have lethal and sublethal impacts on toads, especially on the larvae. Given that amphibians are notably vulnerable to chemical exposure (see Threats), ambient levels of such metals in known and potential boreal toad sites should be maintained at levels at or below those recommended as human health standards.

Timber harvest: At a local level, timber harvest can pose a threat to boreal toads from direct mortality and habitat fragmentation and alteration. Managers should consider the following points:

- ❖ Timber harvests that create uneven-age stands result in fewer disturbances to the understory and ground, which is preferred in boreal toad habitat.
- ❖ Fire and heavy equipment use can cause toad mortality, so post-sale treatments (e.g., scarification or fire) should be limited.
- ❖ Vehicle use of roads and skid trails in boreal toad habitat should be planned to avoid times of peak boreal toad activity (**Table 3**), thus reducing road-kill mortality.
- ❖ Boreal toads disperse considerable distances (2.5 km) from breeding to upland forest sites (Bartelt 2000). Therefore, timber harvest within 2.5 km of known breeding sites should be limited during and immediately following the breeding season.
- ❖ Timber harvest can alter hydrologic patterns, and thus impact boreal toad breeding sites that may not be within the harvest boundaries. Therefore, managers should plan harvest activities designed to maintain water quality and quantity, and hydrologic functioning in proximate wetlands.

Livestock grazing: Several aspects of livestock grazing can be detrimental to boreal toads, but measures can be taken to minimize these impacts. Concentration

of domestic livestock in riparian areas can result in significant direct mortality for boreal toads (especially destruction of egg masses), and it can cause damage to breeding sites and surrounding terrestrial habitat. Therefore, reducing interaction between livestock and boreal toads during critical periods (**Table 3**) is important to minimizing the effects of livestock grazing on boreal toads. This means that livestock access to water sources containing toads should be restricted and possibly eliminated from the beginning of the boreal toad breeding season until, as a minimum, eggs have hatched. However, as discussed previously, livestock concentration around breeding sites can result in reduced survival or significant direct mortality even after hatching.

Standard practices intended to maintain healthy riparian areas, as related to livestock grazing, will protect boreal toad habitat. The average height of *Carex* spp. should not drop below 3 to 4 inches in spring use pastures and 4 to 6 inches in summer/fall use pastures. A minimum of 75 percent of the streambank or shoreline should be maintained in stable condition with adequate vegetation or rock/channel characteristics to prevent erosion.

The desired future condition for boreal toad habitats can be generally achieved by implementing the following practices in boreal toad habitat where livestock grazing occurs:

- ❖ Maintain riparian areas and wetlands in proper functioning condition by conserving adequate vegetation, landform, or debris to:
 - ❖ dissipate energy associated with stream flow, wind, and wave action
 - ❖ filter sediment, capture bedload, and aid floodplain development
 - ❖ improve flood-water retention and groundwater discharge
 - ❖ develop root masses that stabilize stream banks against current action
 - ❖ develop diverse pond characteristics to provide habitat, water depth, duration, and temperature to support diverse aquatic life (USDI Bureau of Land Management 1993).
- ❖ Maintain water quality and quantity at Clean Water Act standards as a minimum.
- ❖ Maintain vegetative cover requirements necessary to meet the recovery needs of boreal toads (see “Habitat” section).

- ❖ Locate toad movement corridors and protect them from the impacts of livestock grazing.
- ❖ Minimize incidences of trampling by livestock by fencing critical habitat areas.

Fire management: Fire may negatively impact boreal toad populations (see “Extrinsic threats” section). Therefore, in areas where there are known boreal toad breeding sites, burning prescriptions should buffer habitats within 2.5 miles of the site and/or should be restricted to late fall through early spring, when boreal toads are less active. If prescribed fires cannot be avoided at these times and locations, then minimizing the rate of spread may allow toads to escape the flames. The use of fire retardants in or near boreal toad habitats, especially breeding sites or other aquatic habitats, should be avoided. Prescribed fires are not a common management activity in the spruce-fir zone where most boreal toad populations are found, so this may not be a common concern.

Pesticides, herbicides, and environmental contaminants: Residue from pesticide, herbicide, or fertilizer application can contain compounds detrimental to toads (see “Extrinsic threats” section). Until the lethal and sublethal impacts of these commonly used chemicals are examined for all life history stages of the boreal toads, they should not be applied within at least 100 meters of wetlands.

Non-indigenous species: Non-indigenous fish and amphibians can potentially negatively impact boreal toad populations as predators, competitors, vectors for pathogens, or as a consequence of management actions that target non-indigenous species (see “Extrinsic threats” section). There is evidence that direct predation by non-indigenous fish is unlikely to pose a serious threat to boreal toads as it often does to other native amphibian populations. However, to protect boreal toad populations from the other potential threats posed by the presence of non-indigenous species, introductions of native and non-native fish and amphibians into occupied or suitable unoccupied boreal toad breeding habitats should be discouraged. Given the expense of removing established exotic species and the uncertainty associated with the impact their presence has on boreal toad populations, we do not currently recommend the removal of non-native species solely for the benefit of boreal toads. Such action could, however, be essential to re-establish or maintain other native amphibians. Managers should keep the potential implications of non-native species in mind when developing management or conservation strategies for mountain lakes and

streams, and consider removal of these species where their presence is deemed detrimental to boreal toad populations or the larger native amphibian community.

Fish toxins kill boreal toad tadpoles, and their effects on adult toads are unclear. Therefore, their use should be limited to actions seeking to remove non-native fish or to replace them with native species. In such a case, piscicides should only be used after tadpoles have metamorphosed.

Habitat development and fragmentation: A variety of activities can fragment boreal toad habitat to the point where populations are adversely affected (see “Extrinsic threats” section). Following are recommendations to deal with water projects, roads, and recreational activities, which would be the most common activities for USFS managers to consider.

Water projects: In most cases, water projects should strive to restore and/or maintain natural, pre-settlement hydrologic processes in wetlands that provide habitat for boreal toads. Water for livestock or irrigation should mimic the natural hydrologic patterns of the drainage and insure that water flow out of impoundments is sufficient to maintain downstream boreal toad habitat. Irrigation ditches in upland areas should be constructed to allow passage of water into natural wetlands and stream corridors, and should avoid such sites so as not to serve as a drain. Irrigation ditches should also be designed to allow for the escape of toads that get trapped in them. New water diversion structures should not be placed in areas with occupied and suitable but unoccupied breeding habitats. Further, water diversion structures located outside occupied boreal toad habitats, but within the same drainage, should not divert water from breeding habitats. Fill material from water diversion projects (including sediments and bank vegetation) should not be placed in suitable boreal toad habitat. Newly constructed impoundments can be made compatible with boreal toad breeding by creating shallow shoreline margins. In these and existing impoundments with boreal toad breeding populations, water levels should be maintained at a depth of at least 1 ft. (0.3 m) with gently sloping banks, so that water is sufficient for egg development.

Wetlands in occupied boreal toad habitat and suitable but unoccupied boreal toad habitats should not be drained or filled. If this is unavoidable, lost wetlands should be replaced at a minimum 2:1 ratio (i.e., two hectares of wetland should be created for each hectare lost). Development within at least 300 ft. (100 m) of

known occupied and suitable but unoccupied boreal toad habitats should be avoided. This will help to avoid the negative impacts of channelization and destabilization of stream banks and can minimize the effects of human disturbances from trampling toadlets, disturbing egg masses, tadpoles, and adults, and contamination and sedimentation of toad habitat.

Roads: Roads on USFS lands in Region 2 are often located along riparian zones and low-lying landscapes. Consequently, they have the potential for causing significant impacts to boreal toads at both the local and regional levels. Existing roads in occupied boreal toad habitats should be examined to determine whether they are a barrier to toad movement. Roads that represent a barrier to safe movement by toads between essential habitats (e.g., between ponds and uplands, or between neighboring ponds) should be modified, possibly by installing culverts or similar structures that allow toads to pass unhindered. Bridges and seasonal road closures may also be used to provide mitigation. Roads could be moved to avoid impact altogether. New roads should avoid suitable toad habitat and contain appropriate features to eliminate barriers to water flow and toad movement.

Roads leading to sensitive wetlands may be seasonally or permanently closed to reduce use of those areas. Interpretive signs explaining modifications of travel should be posted in any area where modifications alter public access. This will improve the public’s acceptance and compliance with these restrictions.

Recreation: Campsites in or near occupied breeding ponds should be closed seasonally to protect breeding adults, egg masses, tadpoles, and toadlets. In unrestricted camping areas, fencing and signs should be used to seasonally restrict camping within at least 100 ft. (34 m) of riparian areas. As with roads, interpretive signs explaining changes should be posted to improve the public’s acceptance and compliance with these restrictions.

The impacts from trail use should be evaluated annually in areas where they cross boreal toad breeding habitat. Trails that lead to or pass near occupied breeding sites should be closed seasonally, or permanently re-routed to avoid these areas. Newly constructed trails should avoid directing users to occupied breeding sites, and a buffer at least 100 ft. (34 m) should be placed between new trails and occupied breeding sites. Off-road vehicle use should be managed to avoid riparian and wetland habitats.

Development of new ski areas or expanded terrain should avoid occupied boreal toad breeding, foraging, and over-wintering habitats. For existing and planned ski areas, managers should evaluate how water removal for snow-making would affect wetland hydrology and then recommend appropriate mitigation measures.

Captive propagation and reintroduction:

A detailed description of captive propagation and reintroduction methods for boreal toads is presented by Loeffler (2001), and general information by Semlitsch (2000). Boreal toads from the SRMP are currently being bred in captivity at several facilities, including the Colorado Division of Wildlife Native Aquatic Species Restoration Facility (NASRF), the Toledo Zoo, and the Cheyenne Mountain Zoo. As of November 2002, the NASRF housed approximately 600 boreal toads representing 48 distinct genetic lots from 20 breeding areas throughout Colorado (Scherff-Norris et al. in prep.). Currently the NASRF plans to supplement this breeding stock and to enhance genetic diversity by collecting additional boreal toad eggs and tadpoles. They have also begun tracking the breeding success and genetics of the captive population at NASRF via an American Zoological Association-approved studbook. Seven boreal toads (three adult females, one adult male, and three juveniles) from Wyoming's southern population are being held at the Saratoga Fish Hatchery. Four of these toads were collected from Ryan Park and three from Bird Creek in the Medicine Bow Mountains.

Reintroduction (often referred to as translocation or repatriation) efforts have been unsuccessful in Wyoming and in Colorado (Muths et al. 2001). In 1996 and 1997, the Wyoming Game and Fish Department released 4300 juvenile boreal toads and 950 tadpoles, respectively, into beaver ponds near Owen Lake in the Medicine Bow Mountains. Surveys of these sites recorded no boreal toad observations from 1998 through 2000, indicating that the reintroduction effort was unsuccessful. On the other hand, some recent success has been shown with reintroductions on the Grand Mesa, Colorado (preliminary data in CDOW 2004). Exactly why some reintroductions fail and others show promise has not been determined; but future efforts are none-the-less planned for Carson National Forest in New Mexico, Rocky Mountain National Park in Colorado, and northern Colorado if suitable sites can be found.

Several key limitations must be addressed prior to the reintroduction of toads. First, it must be determined with thorough surveys that boreal toads are extirpated

from a large, historically occupied area. Second, it must be unlikely that the selected reintroduction site will be re-colonized by natural migration from adjacent populations. Finally, it must be determined that the proposed reintroduction site has adequate, suitable, properly positioned habitats to support a population of boreal toads. Once these requirements have been investigated, the site must be tested to determine whether there are any significant imminent threats in the area that could result in the extirpation of boreal toads. The following habitat elements should be investigated:

- ❖ Water quality should be tested, particularly the pH and levels of toxins, such as heavy metals, organochlorides, and organopesticides.
- ❖ Substrates should also be sampled for the presence of toxins.
- ❖ The environment and amphibians or fish in the area should be tested for pathogens.
- ❖ The site should be surveyed for introduced flora and fauna that may present a threat to boreal toads.
- ❖ Surveys should evaluate the presence and abundance of predators (e.g., garter snakes, predaceous diving beetles, and tiger salamanders).
- ❖ Present and anticipated land use and ownership, including stream flow and water rights, should be assessed.

Successful translocation of boreal toads will depend on methods/policy to identify appropriate sites, including identification of disease issues, and intensive follow-up to see what factors cause the failure/success of particular translocations. Once these elements are addressed and there are adequate, preferably wild (or if necessary captive) toads, then reintroduction efforts should proceed following the methods outlined by Loeffler (2001).

Inventory and monitoring

The Boreal Toad Recovery Team is a collection of expert amphibian biologists from the Rocky Mountains, and their recovery plan is (Loeffler 2001) considered the best available source for inventory and monitoring practices for boreal toads in this area. Copies of the current version of the Boreal Toad Conservation Plan and Agreement, from which the following discussion

is derived, are available from the Colorado Division of Wildlife. Further, all amphibian researchers should study and follow the guidelines presented in the National Wildlife Health Center's Standard Operating Procedures for Amphibians (http://www.nwhc.usgs.gov/research/amph_dc/amph_sop.html).

Disease mitigation: There is no known way of eliminating BD once it has infected a site. Therefore, one of the most important elements in any amphibian inventory and monitoring program is a standard method for minimizing the spread of disease agents and parasites between study sites. This is especially important with boreal toads since BD is lethal to toads and apparently spreading rapidly. The Declining Amphibian Population Task Force developed the following *Code of Practice* (e.g., <http://ventura.fws.gov/es/protocols/dafta.pdf>) for minimizing the spread of pathogens among amphibian populations:

- 1) Remove mud, snails, algae, and other debris from nets, traps, boots, vehicle tires, and all other surfaces. Rinse cleaned items with sterilized (e.g., boiled or treated) water before leaving each study site.
- 2) Scrub boots, nets, traps etc. with a 70 percent ethanol solution and rinse clean with sterilized water between study sites. Avoid cleaning equipment in the immediate vicinity of a pond or wetland.
- 3) In remote locations, clean all equipment upon return to the lab or "base camp" as described above, or with a bleach solution of 1 part bleach to 32 parts water, or stronger. Elsewhere, when washing-machine facilities are available, remove nets from poles and wash them with bleach solution in a protective mesh laundry bag on a "delicate" cycle.
- 4) When working at sites with known or suspected disease problems, or when sampling populations of rare or isolated species, wear disposable gloves and change them between handling each animal. Dedicate sets of nets, boots, traps, and other equipment to each site visited. Clean and store them separately at the end of each field day.
- 5) When amphibians are collected, ensure the separation of animals from different sites

and take great care to avoid indirect contact between them (e.g., via handling, reuse of containers) or with other captive animals. Isolation from unsterilized plants or soils that have been taken from other sites is also essential. Always use disinfected/disposable husbandry equipment.

- 6) Examine collected amphibians for the presence of diseases and parasites soon after capture. Prior to their release or the release of any progeny, amphibians should be quarantined for a period and thoroughly screened for the presence of any potential disease agents.
- 7) Dispose of used cleaning materials (e.g., liquids) safely, taking them back to the lab for proper disposal, if necessary. Used disposable gloves should be retained for safe disposal in sealed bags.

Survey methods: Surveys for boreal toads typically use the Visual Encounter Survey (VES) method, which has become a standard in amphibian research (e.g., Campbell and Christman 1982, Crump and Scott 1994, Heyer et al. 1994) and is being systematically applied by national programs such as the Amphibian Research and Monitoring Initiative (ARMI; <http://armi.usgs.gov/>). VES is conducted by observers walking through a set area, for a set length of time, in a set pattern and visually searching for animals. For amphibians, this usually means walking along the perimeter of wetlands scanning for amphibians, eggs, or larvae. There are advantages and disadvantages to using this technique. Advantages include:

- ❖ little equipment is needed
- ❖ it can be conducted by as little as one person
- ❖ it is compatible with stratification by environmental variables
- ❖ it is readily scalable from small to very large areas
- ❖ pond breeding amphibians, that are generally clumped in defined habitat areas and are difficult to trap, are good subjects for VES
- ❖ it is readily applicable to the Proportion of Area Occupied method of evaluating amphibian populations (see below).

Disadvantages include:

- ❖ data collected yields information on the presence of a species but does not establish absence
- ❖ it does not give reliable estimates of abundance
- ❖ it is highly susceptible to observer bias, so only reliable, experienced observers should participate
- ❖ it only applies to easily observed species
- ❖ when applied to boreal toads, the standard procedure appears to reveal only a small proportion of adults actually present at a given site (Boreal Toad Recovery Team 2003).

A newly emerging possibility for surveys in riparian corridors involves the use of aquatic hoop nets to capture toads that make in-channel movements (Young and Schmetterling 2004). This is a standard practice in fisheries biology (Schreck and Moyle 1990) that shows promise for both detecting the presence of toads in a drainage and monitoring their in-stream movements. Managers are advised to monitor communications from the BTRT to learn if this method becomes a recommended survey method for boreal toads and, in such an event, to learn the best techniques for application.

Any manager seeking to conduct boreal toad surveys should obtain the references noted above and contact the Colorado Division of Wildlife's BTRT to learn the best techniques possible. We offer some additional, general guidance below:

- ❖ Selecting sites: The BTRT recommends the following priorities for surveying boreal toad habitat: 1) known historic locations, 2) areas expected to be affected by management activities, 3) areas with suitable habitat. Given typically limited funds for boreal toad conservation, delineation of possible habitat and actual field surveys for boreal toads are not recommended outside the known historic range of the toad, nor are they recommended in ecosystems where boreal toads are not known to occur (e.g. sagebrush desert, low elevation grasslands, etc.). Viable, but previously unknown, breeding populations in such areas are unlikely, and conservation

efforts will be more fruitful if targeted within the range and habitats described in this assessment. Potential habitat can be identified using wetland inventory, elevation, and historical distribution data from boreal toad databases such as those housed at the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database.

- ❖ Selecting specific locations within a site: An important element in conducting surveys for boreal toads is targeting appropriate habitats. Metamorphosed boreal toads are usually associated with wetland habitats above 2,440 m (8,000 ft.), including ponds, bogs, willow thickets, and streams. Toads use a wide variety of lentic areas for breeding, from tire ruts to large lakes. Females usually deposit eggs in shallow water, and during the day larvae concentrate in shallow, sunny margins of the water body. For a more thorough discussion of habitat preferences, see the "Habitat" section. Further, detailed information on habitat characteristics recorded during surveys at sites occupied by boreal toads helps to refine specific habitat criteria that can be used to focus survey efforts only in suitable habitats.
- ❖ Field approach: As it is easy to damage eggs, it is important to avoid wading through water in search of eggs and tadpoles, especially in shallow aquatic vegetation. In large wetlands (e.g., bogs or willow thickets) it is best if survey crew members spread out and make broad zig-zags through the site to ensure complete coverage.
- ❖ Timing: It can be extremely difficult to detect adult boreal toads after the breeding season. Timing surveys to target specific periods in the boreal toad life cycle (**Table 3**) can improve the success of survey efforts. Therefore, surveys targeting adults during the breeding season followed up by surveys for metamorphs in mid- to late summer can be an effective method to maximize the probability of detecting boreal toads at a survey location.
- ❖ Recording data: It is important to complete survey data sheets for all sites visited, whether or not any boreal toads were observed. This negative information allows researchers

to determine long-term information on the distribution and abundance of boreal toads by distinguishing between sites where no surveys have been conducted and sites where surveys were conducted and no toads were observed. Additionally, habitat surveys should include testing any toads found for the presence of BD.

- ❖ Storing data: It is also very important to have a centralized repository for all boreal toad information collected by past and future surveys. Agencies should develop explicit survey standards, including reporting of Geographic Positioning System information. This can remove many of the questions that come up regarding exactly where a field crew went or how much of an extensive site they were able to survey.
- ❖ Interpreting presence: It is essential in conducting surveys for boreal toads that standards for what constitutes a positive occurrence are established. Presence is conclusive if boreal toad adults, eggs, or larvae are observed and identified correctly. However, a lack of observations of boreal toads is never conclusive that boreal toads are not present. A single survey of a location is not a reliable means for determining presence or absence because toads are cryptic and sub-adults usually do not congregate at survey sites.
- ❖ Data analysis: A focus on numbers of populations in a landscape rather than numbers of individuals in a particular population is often appropriate when asking questions about amphibian decline. This general approach has been modified to a standard protocol known as Proportion of Area Occupied (PAO; <http://edc2.usgs.gov/armi/PAOEstimator.asp>). This technique provides data to track amphibian populations by evaluating the portion of the landscape that is occupied rather than the actual abundance of individuals (MacKenzie et al. 2002). The reasoning for this is largely one of maximizing area evaluated per unit effort. Secondarily, it should be noted that finding a decline in the area occupied by amphibians across an entire landscape can be more informative than tracking one population whose numbers are decreasing. A single

population may be going through a natural boom-bust cycle whereas a decrease in the number of population segments across a region suggests a more widespread problem.

Known breeding sites should be surveyed during daylight hours at least weekly during the breeding season to search for adult toads and to determine the number of egg masses deposited and the development and metamorphosis of larvae. It is very helpful when conducting this type of monitoring to flag the location of known egg masses as they are found so that new egg masses can be identified and so that egg masses are not damaged during future surveys. Night surveys should also be conducted at least once a week during the breeding season to determine the number of adult toads present at breeding sites. These night surveys should be conducted between one hour after sunset and midnight, and they should focus on the immediate vicinity of the wetland. Relative abundance should be determined from a count of adults from a single circuit of the wetland.

After the breeding season, sites with known breeding activity should be monitored at least once every two weeks during the rest of the summer, or until all larvae have metamorphosed and dispersed. In addition to the general data recorded on standardized data sheets, it is useful to sketch the distribution of toads, tadpoles, and eggs on a copy of an aerial photo or a topographical map. This can be very helpful for locating monitoring sites during subsequent seasons, and by different personnel than conducted the initial survey.

The BTRT established a minimum standard for monitoring boreal toad breeding sites. The minimum monitoring effort should include thorough searches of the site at least three times during the breeding season, with each survey being at least five days apart, and including at least one night survey.

Information Needs

The most important information need for boreal toad management is disease research. Specifically, a test to detect the presence of BD in the environment would aid managers in defining suitable habitat for boreal toads. A better understanding of the biology of this fungus in relation to boreal toad population declines would also be valuable.

The distribution of boreal toads is well known in some parts of its range in Region 2. However, there are gaps in our knowledge of locations where current

breeding activity is occurring. Increased survey efforts in historically occupied areas and monitoring of known survey sites would help managers to determine whether previously documented breeding sites remain active and to identify heretofore-unknown breeding sites. Maintaining an up-to-date, comprehensive database of boreal toad locations for Region 2 through the Colorado Natural Heritage Program and the Wyoming Natural Diversity Database will also aid in disseminating information on the current distribution and information gaps to land managers.

There is generally good information on the demography of boreal toads, but information on specific populations is lacking. Annual monitoring of population trends at breeding sites is needed to determine population viability and there are suitable methods available to monitor population trends for boreal toads (Loeffler 2001). Ideally, all known breeding sites should be visited several times per year in order to determine reproductive effort and survival. Research needs to be conducted to model population viability at local and regional scales in Region 2. Ongoing research at Colorado State University to model boreal toad population declines relative to BD and environmental trends is beginning to address this information need (R. Sherer personal communication 2003). Greater knowledge of the boreal toad's life history from metamorphosis to recruitment in the breeding population would aid our understanding of what factors influence recruitment rates in boreal toad populations.

Additional genetic studies are needed to clarify the taxonomic status of the SRMP and the NRMP and the range limits of these populations. Information on boreal toad home range size, dispersal, and hibernacula habitats is also lacking.

The response of boreal toads to fine and broad scale changes in habitat is not completely understood.

Further research is needed in order to evaluate the positive and negative effects of threats (identified earlier in this document) to boreal toad populations and their habitat. Changes in boreal toad reproduction, rearing, resting, foraging, and dispersal ability can be examined using targeted manipulative experiments to determine pre- and post-treatment conditions and consequent differences in boreal toad populations. The response of boreal toads to changes in habitat relative to predators could also be researched more thoroughly in Region 2. Data is also needed describing the effects of piscicide treatments such as rotenone and antimycin on survival during the tadpole stage.

There is no detailed information on how insect prey population's response to habitat changes affects boreal toads. Boreal toads appear to be very flexible in their diet and, therefore, may shift prey items if one group of prey becomes locally scarce due to habitat changes. Future research should investigate how specific prey species respond to habitat changes from management actions and what if any affect this may have on boreal toads.

The movement patterns of boreal toads have been well documented by Bartelt (2000), and his results indicate that changes to habitat within 2.5 km buffers of breeding sites have the potential to affect boreal toads. Further evaluation of the effects of management activities in proximity to breeding habitat is necessary in understanding how changes in these habitats affect seasonal movement patterns.

Loeffler (2001) has described methods for restoration of boreal toads. However, full implantation of the restoration plan is not currently possible due to the potential for BD to eliminate any re-introduced populations. Captive breeding has been conducted successfully in several facilities, so there is a source population for restoration once the problems with BD infections can be dealt with for re-introduced toads.

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APPENDIX A

Matrix Life-Cycle Model for Boreal Toad

by Dave McDonald and Takeshi Ise

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Background

Matrix models are designed to examine the intrinsic life history of a species (i.e., evolved traits affecting reproduction, or the component of population persistence that is affected by factors internal to the species) rather than extrinsic factors (e.g., habitat availability or the impacts of disease). They are very generalizable models that can be applied successfully to nearly any taxa, including amphibians. The utility of matrix models in biology is primarily to gain insight into the relative contribution of specific ages or life stages of a species to the persistence of wild populations in near-equilibrium conditions. These models are not meant to make judgments on the overall increase or decrease of a population and its likelihood of extinction or to determine the impacts of any specific habitat influences. For instance, consider that populations of an amphibian are declining due to the elimination of breeding ponds resulting from introduction of a disease (an external influence). This does not impact the structure of the model since the intrinsic, evolved traits of the species are not altered (e.g., the remaining

ponds and individuals all have the same vital rates). The fact that specific populations may be in decline (i.e., violating the assumption of the population growth rate being approximately one [$\lambda \approx 1$]) may affect the long-term persistence of those populations, but this will not change the relative contributions of each life stage. If such a decline is affecting one stage to an abnormally high degree, this will be accounted for in developing the life cycle diagram or when parameterizing the model with stage-specific vital rates that best reflect those under current conditions.

The life history described by Keinath and Bennet (2000) provided the basis for a life cycle graph (**Figure A1**) and a matrix population analysis with a post-breeding census (Cochran and Ellner 1992, McDonald and Caswell 1993, Caswell 2000) for the boreal toad. The model has three kinds of input terms: P_i describing survival rates, m_i describing fertilities, and B_i describing probability of reproduction (**Table A1**). **Figure A2a** shows the symbolic terms in the projection matrix corresponding to the life cycle graph. **Figure A2b** gives the corresponding numeric values. The model assumes female demographic dominance so that, for example, fertilities are given as female offspring per female. The population growth rate (λ) is 1.000 based on the estimated vital rates used for the matrix. Although this suggests a stationary population, the value is subject to the assumptions used to derive the transitions and should not be interpreted as an indication of the general well-being and stability of the population. Other parts of the analysis provide a better guide for assessment.

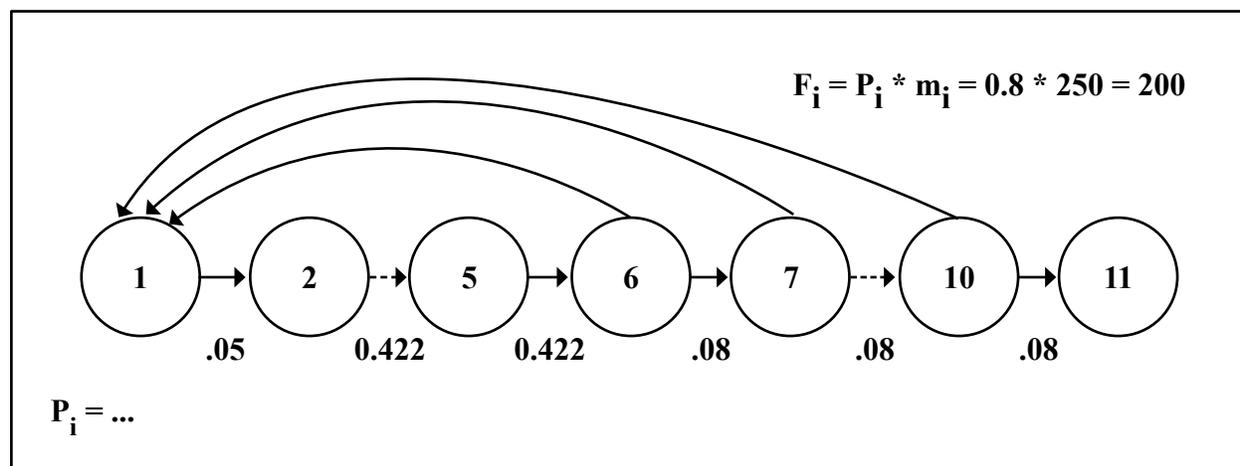


Figure A1. Age-classified life cycle diagram for boreal toad. Note ellipsis of Nodes 3 and 4 ($P_i = 0.422$) and Nodes 8 and 9 ($P_i = 0.8$, $F_i = 200$). Reproductive arcs, F_i , from Nodes 6 through 10 include terms for survival of female parent (P_i) as well as number of female offspring per female (m_i). Survival rate increases from low first-year survival ($P_1 = 0.05$) to higher pre-reproductive survival ($P_i = 0.422$) to high survival of reproductive females ($P_i = 0.8$).

Table A1. Parameter values for the component terms (P_i , m_i , and B_i) that make up the vital rates in the projection matrix for boreal toads.

Parameter	Numeric value	Interpretation
m_6	400	Number of female offspring produced by a female of Age Class 6
m_a	500	Number of female offspring produced by a fully-developed female
B	0.5	Probability of reproduction
P_1	0.05	Annual survival rate of eggs
P_j	0.422	Annual survival rate of pre-reproductive
P_a	0.8	Annual survival rate of reproductive

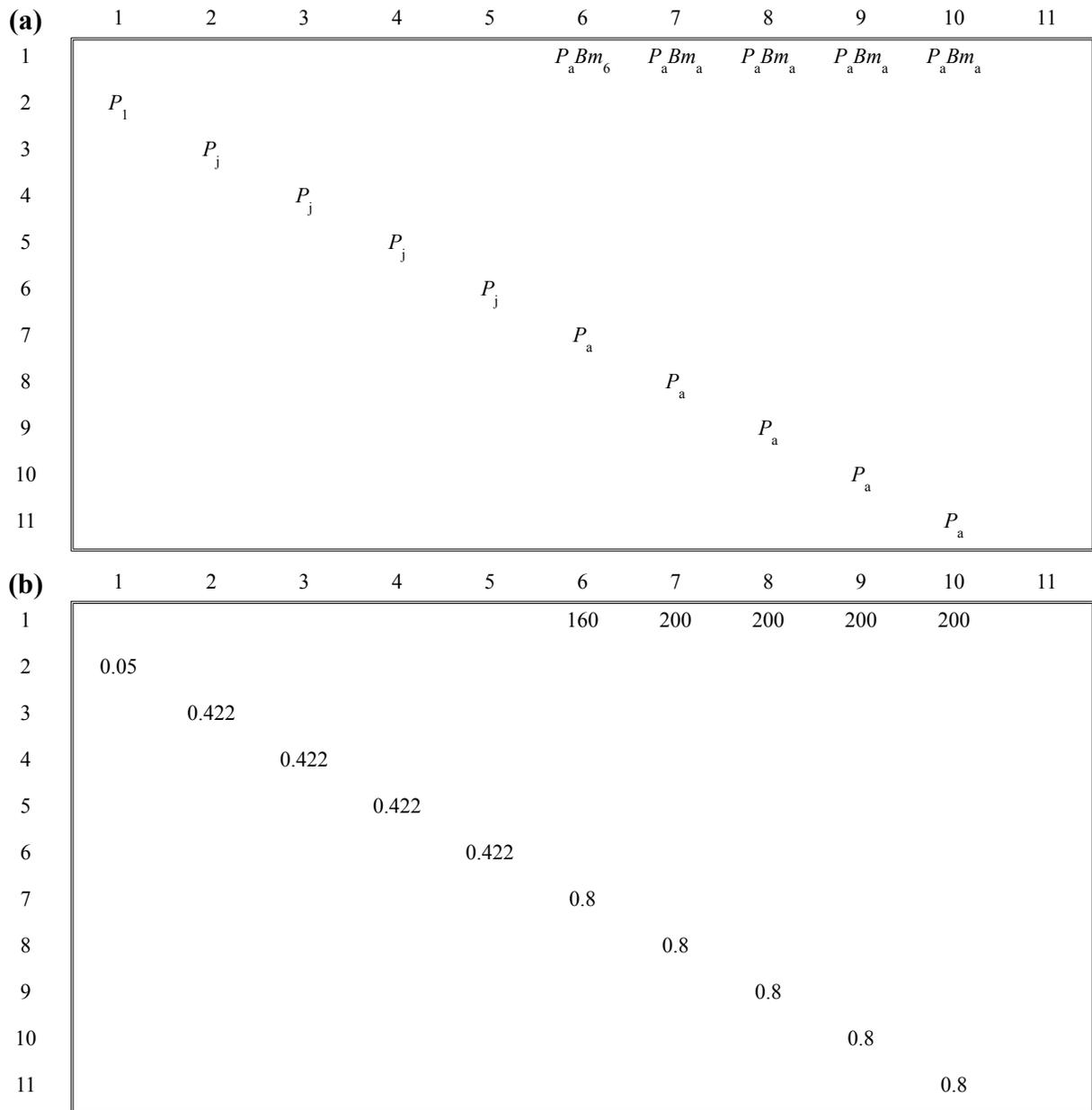


Figure A2. The input matrix of vital rates, \mathbf{A} (with cells a_{ij}) corresponding to the boreal toad life cycle graph ([Figure A1](#)); populated with (a) symbolic values and (b) numeric values.

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. **Sensitivity** is the effect on λ of an **absolute** change in the vital rates (a_{ij} , the arcs in the life cycle graph [Figure A1] and the cells in the matrix, **A** [Figure A2]). Sensitivity analysis provides several kinds of useful information (see Caswell 1989, pp. 118-119). First, sensitivities show “how important” a given vital rate is to λ , or fitness. For example, one can use sensitivities to assess the relative importance of survival (P_i) and reproductive (F_i) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity of data, but it could also result from use of inappropriate estimation techniques or other errors of analysis. In order to improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing λ of endangered species or the “weak links” in the life cycle of a pest. **Figure A3** shows the “possible sensitivities only” matrix for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible – for example, the sensitivity of λ to moving from Age Class 3 to Age Class 2).

In general, changes that affect one type of age class or stage will also affect all similar age classes or

	1	2	3	4	5	6	7	8	9	10	11
1						0.000	0.000	0.000	0.000	0.000	
2	2.611										
3		0.309									
4			0.309								
5				0.309							
6					0.309						
7						0.122					
8							0.081				
9								0.048			
10									0.021		
11										0.000	

Figure A3. Possible sensitivities only matrix, S_p (remainder of matrix consists of zeros). The transitions to which the population growth rate (λ) of boreal toads is most sensitive are highlighted: the survival of eggs (Cell $s_{21} = 2.611$) and the survival of pre-reproductive (Age Classes 2 to 5: $s_{32} = s_{43} = s_{54} = s_{65} = 0.309$).

stages. For example, any factor that changes the annual survival rate of Age-class 6 females is very likely to cause similar changes in the survival rates of other “adult” reproductive females (those in Age Classes 7 through 10). Therefore, it is usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For this model, the result is that the sensitivity of λ to changes in first-year survival (2.611; 63 percent of total) is considerably larger than it is to changes in other rates. The summed “pre-reproductive” survival sensitivity is 1.236 (30 percent of total), and the summed “reproductive” survival sensitivity is 0.272 (7 percent of total). Boreal toads show virtually no sensitivity to changes in fertility (the first row of the matrix in **Figure A2**). The major conclusion from the sensitivity analysis is that enhancement of first-year survival (survival of eggs, emergent tadpoles and through the first winter) is the key to population viability.

Elasticity analysis

Elasticities are useful in resolving a problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading because survival rates and reproductive rates are measured on different scales. For instance, a change of 0.5 in survival may be a big alteration (e.g., a change from a survival rate of 90 to 40 percent). On the other hand, a change of 0.5 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Elasticities are the sensitivities of λ to **proportional** changes in the vital rates (a_{ij}) and thus largely avoid the problem of differences in units of measurement. The elasticities have the useful property of summing to

1.0. The difference between sensitivity and elasticity conclusions results from the weighting of the elasticities by the value of the original arc coefficients (the a_{ij} cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction (F_i) and survival (P_i) for a given species.

Elasticities for boreal toads are shown in **Figure A4**. The λ of boreal toads is most elastic to changes in the survival of eggs (Age Class 1) and the survival of “pre-reproductive” females (Age Classes 2 to 5). The sensitivities and elasticities for boreal toads correspond in the relative magnitude of the three most important transitions, a phenomenon that is not always the case in other life histories (*cf.* Townsend’s big-eared bat, plains killifish). Note, however, that the sensitivity is much more concentrated on first-year survival whereas the elasticity places equal emphasis on survival through the first five age-classes. The same absolute change in survival rate will have a larger impact on the very low first-year rate than it will on the higher rates for later age-classes. The survival rates through the first five age-classes are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis.

Partial sensitivity and elasticity

Partial sensitivity and elasticity analysis assesses the impact on λ of changes in “lower-level terms” (Caswell 2000, pp. 218 and 232). Some transitions

(e.g., the F_i) include lower-level component terms (P_i , m_i , and B_i) related to the different kinds of transitions in the life cycle (e.g., survival, fertility, and breeding probability terms). Partial sensitivity results indicate that changes in the P_i (survival rates) will have virtually the only impact on λ (100.0 percent of the total partial sensitivity). Changes in fertility (m_i) and probability (B_i) will have practically no impact on λ (0.0 percent of the total partial sensitivity). Similarly, P_i terms account for 100.0 percent of the total partial elasticity, with 0.0 percent accounted for by m_i and B_i terms. Again, every aspect of the analysis suggests that boreal toads are most susceptible to factors that affect the first-year survival.

Other demographic parameters

The **stable (st)age distribution (SAD; Table A2)** describes the proportion of each Stage (or Age Class) in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable age distribution, regardless of whether the population is declining, stationary or increasing. Under most conditions, populations not at equilibrium will converge to the SAD within 20 to 100 census intervals. For boreal toads at the time of the post-breeding annual census (just after the end of the breeding season), eggs represent 91 percent of the population because amphibians generally lay numerous eggs compared to the number of adults. Therefore, for this research, we excluded eggs from the calculation of the stable age distribution. At the time of the census, 93 percent of the (non-egg) population consists of juvenile stages, and the remaining 7 percent consists of adult stages. **Reproductive values (Table A3)** can be thought of as

	1	2	3	4	5	6	7	8	9	10	11
1						0.033	0.033	0.026	0.021	0.017	
2	0.131										
3		0.131									
4			0.131								
5				0.131							
6					0.131						
7						0.098					
8							0.064				
9								0.038			
10									0.017		
11											0.000

Figure A4. Elasticity matrix, **E** (remainder of matrix consists of zeros). The population growth rate (λ) of boreal toads is most elastic to changes in first-year survival (Cell $e_{21} = 0.131$) and the survival of pre-reproductives (Age Classes 2 to 5: $e_{32} = e_{43} = e_{54} = e_{65} = 0.131$).

Table A2. Stable age distribution (right eigenvector) for females, with Age Class 1 (first-year/eggs) excluded. At the census, 93 percent of the non-egg individuals in the population should be pre-reproductive. The remaining 7 percent of individuals will be reproductive adults.

Age Class	Description	Proportion
2	Prereproductive	0.558
3	“ ”	0.235
4	“ ”	0.099
5	“ ”	0.042
6	First reproduction ($F_i = 160$)	0.018
7	Reproductive ($F_i = 200$)	0.014
8	“ ”	0.011
9	“ ”	0.009
10	“ ”	0.007
11	Maximum Age Class	0.006

Table A3. Reproductive values for females. Reproductive values can be thought of as describing the “value” of an age class as a seed for population growth relative to that of the first (newborn or, in this case, egg) age-class. The reproductive value of the first age-class is always 1.0. The peak reproductive value is highlighted.

Age Class	Description	Proportion
1	Eggs	1.00
2	Prereproductives	20.01
3	“ ”	47.43
4	“ ”	112.42
5	“ ”	266.50
6	First reproduction ($F_i = 160$)	631.74
7	Reproductives ($F_i = 200$)	589.94
8	“ ”	487.69
9	“ ”	359.82
10	“ ”	199.93
11	Maximum Age Class	0.00

describing the “value” of a stage as a seed for population growth relative to that of the first (newborn or, in this case, egg) stage. The reproductive value of the first stage is always 1.0. A female individual in Age Class 2 is “worth” 20 female eggs, and so on (Caswell 2001). The reproductive value is calculated as a weighted sum of the present and future reproductive output of a stage discounted by the probability of surviving (Williams 1966). As in many species with high clutch sizes, the peak reproductive value (632 at Age Class 6) is considerably higher than that of the eggs (**Table A3**). The reproductive value analysis complements the results from the elasticity and sensitivity analyses. Only by increasing survival rates of earlier age-classes can we increase the number of large, fertile females that are the mainstay of the population. Whereas peak reproductive value often occurs at age of first reproduction (Keyfitz 1985), in this case the increasing fertility of larger, older

females causes the peak to occur four years after the age-class of first reproduction. The cohort generation time for boreal toads is 7.7 years (SD = 1.4 years).

Stochastic model

We conducted a stochastic matrix analysis for boreal toads. We incorporated stochasticity in several ways, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (**Table A4**). Under Variant 1, we altered the fertilities (F_i). Under Variant 2, we varied only the survival of the female eggs, P_{21} . Under Variant 3, we varied the survival of all age classes, P_i . Variant 4 combined stochasticity in the fertilities with stochasticity in first-year survival. Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the Stable Age Distribution (SAD) under

Table A4. Summary of five variants of stochastic projections for boreal toads.

	Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Input factors:					
Affected cells	F_i	P_1	P_i	$F_i + P_{21}$	P_i
S.D. of random normal distribution	1/4	1/4	1/4	1/4	1/3.5
Output values:					
Deterministic λ	1.00035	1.00035	1.00035	1.00035	1.00035
# Extinctions / 100 trials	0	0	30	0	65
Mean extinction time	—	—	1,454.4	—	1,280.0
# Declines / # survived populations	19/100	50/100	66/70	67/100	31/35
Mean ending population size	18,542.9	17,689.1	2,270.7	24,712.2	621,821.0
Standard deviation	12,509.1	22,768.6	6,998.7	65,902.1	3,400,000
Median ending population size	15,959.6	9,616.54	53.64	5,379.04	41.46
Log λ_s	0.00020	-0.000206	-0.00351	-0.000170	-0.00586
λ_s	1.0002	0.9998	0.9965	0.9998	0.9942
% reduction in λ	0.0147	0.055	0.385	0.052	0.619

the deterministic model. Beginning at the SAD helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We varied the amount of fluctuation by changing the standard deviation of the random normal distribution from which the stochastic vital rates were selected. The default value was a standard deviation of one quarter of the “mean” (with this “mean” set at the value of the original matrix entry [vital rate], a_{ij} under the deterministic analysis). Variant 5 affected the same transition as Variant 3 (P_{21}) but was subjected to slightly larger variation (SD was $1 / 3.5$ [= 0.286 compared to 0.25] of the mean). We calculated the stochastic growth rate, $\log \lambda_s$, according to Eqn. 14.61 of Caswell (2000), after discarding the first 1,000 cycles in order to further avoid transient dynamics.

The stochastic model (**Table A4**) produced two major results. First, altering the survival rates had a much more dramatic effect on λ than did altering all the fertilities. For example, the median ending size under the varying fertilities of Variant 1 (12,509) actually increased slightly from the starting size of 10,000. In contrast, varying the survival of eggs under Variant 2 resulted in a median ending size of 9,616.5. Varying the survival rates of all age classes under Variant 3 resulted in a much more dramatic decline of median size (53.6). This difference in the effects of stochastic variation is predictable from the sensitivities and elasticities. λ was more sensitive and elastic to changes in any of the first five P_i than it was to changes in the entire set of fertilities, F_i . The importance of elasticities is highlighted by the much larger impact of varying all the P_i compared to varying just first-year survival.

Second, large-effect stochasticity has a negative effect on population dynamics, at least when it influences transitions to which λ is highly sensitive. This negative effect occurs despite the fact that the average vital rates remain the same as under the deterministic model – the random selections are from a symmetrical distribution.

This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2000). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization will therefore be most likely to end at a population size considerably lower than the initial population size. For boreal toads under the survival Variant 3, 30 out of 100 trials of stochastic projection went to extinction vs. 0 under the fertilities Variant 1. Variant 5 shows that the magnitude of fluctuation has a potentially large impact on the detrimental effects of stochasticity. Increasing the magnitude of fluctuation also increased the severity of the negative impacts – the number of extinctions went from 30 in Variant 3 to 65 in Variant 5 when the magnitude of fluctuation was slightly amplified. These results suggest that populations of boreal toads are relatively tolerant to stochastic fluctuations in production of eggs (due, for example, to annual climatic change or to human disturbance) but extremely vulnerable to variations in the survival of adult stages. Variant 4 suggests that if stochasticity in fertility and survival are uncorrelated (as assumed here) variability in egg production may actually help buffer the detrimental effects of variability in survival rates.

Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive transitions in their life cycles. A possible concern is that anthropogenic impacts may induce variation in previously invariant vital rates (such as annual adult survival), with consequent detrimental effects on population dynamics. Further, in the case of amphibians with high sensitivity of λ to changes in first-year survival, selection may be relatively ineffective in reducing variability that surely results from a host of biotic and abiotic factors.

Potential refinements of the models

Clearly, the better the data on survival rates, the more accurate the resulting analysis. Data from natural populations on the range of variability in

the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of “stochastic” matrices that mirrored actual variation. One advantage of such a series would be the incorporation of observed correlations between variation in vital rates. Where we varied F_i and P_i values simultaneously, we assumed that the variation was uncorrelated, based on the assumption that factors affecting reproduction and, for example, over-winter survival would occur at different seasons or be due to different and likely uncorrelated factors (e.g., predation load vs. climatic severity or water levels). Using observed correlations would improve on this assumption by incorporating forces that we did not consider. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.

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