

Amphibians

OVERVIEW

Amphibians are an important component of the aquatic and terrestrial ecosystems of the Greater Yellowstone Network (GRYN). Although frequently overlooked in accounts of the region's wildlife, amphibians are much appreciated by park visitors and especially by children, who are gifted at finding them. People associate the occurrence of amphibian species with healthy wetland habitats. From a scientific perspective, amphibians constitute an important part of the food web by consuming insects and other invertebrates, and by providing a food source for a long list of fish, reptile, bird, and mammal species, and even some predatory aquatic insects. Tadpoles influence aquatic ecosystems by grazing algae and aquatic plants. They enrich terrestrial ecosystems by transferring the energy stored in aquatic plants to tadpole-eating animals. Amphibians act as indicators of ecosystem health; their permeable skin and complex life history makes them particularly sensitive to environmental pollutants, habitat modification, and climate change.

Distribution

Following is a short description of the distribution throughout the US of each of the amphibian species found in the GRYN. For further information about their distribution within the parks, please refer to the accompanying atlas.

Tiger salamanders (*Ambystoma tigrinum*) are widespread across the US, being found in all locations except the northeast, southern Florida, the Great Basin, and most of the Pacific coast. Museum records and modern observations indicate widespread occurrence of the tiger salamander in the parks of the GYE, particularly at lower elevations.

The western or boreal toad (*Bufo boreas boreas*) is found in the western US, from the West coast inland to Colorado. Boreal toads are generally widespread in the parks of the GYE but are only occasionally found above 8,000 feet elevation.

The boreal chorus frog (*Pseudacris maculata*) is found primarily in the central portion of the continent, including the Rocky Mountains and central plains regions. In the GYE, boreal chorus frogs are widespread, common, and often abundant in areas with standing water in springtime. Boreal chorus frogs occupy a wide range of elevations in the GYE. They also occur in suitable habitats in BICA.

The Columbia spotted frog (*Rana lutiventris*) occupies large portions of Washington, Oregon, Montana, Idaho, and Wyoming, with disjunct populations in northern Utah and

Nevada. Within the parks of the GYE, it is widespread, common, and found at all elevations ranging to the subalpine zone. Due to its habit of basking in the sun alongside streams and ponds, this is the most frequently seen amphibian of the GYE.

The northern leopard frog (*Rana pipiens*) has a large range encompassing much of the northeast, midwest, and the interior western states. This species historically occurred in Jackson Hole but has not been documented since the mid-1990s. Its presence has not been confirmed in Yellowstone (Koch and Peterson 1995). Northern leopard frogs occur in suitable habitat in BICA.

The American bullfrog (*Rana catesbeiana*) is found in most of the US but is native only east of the Rockies. It has been introduced at many locations in the western US. In the GYE, bullfrogs are known to occur only in a small portion of Jackson Hole (Koch and Peterson 1995). No records are known from BICA.

The plains spadefoot (*Spea bombifrons*) occurs mainly on the eastern and southern outwash plains of the Rocky Mountains, in Montana, eastern Wyoming and Colorado, New Mexico, the Great Plain states, Texas, and eastern Arizona. This species occurs in BICA, near the western edge of its range in Wyoming.

The Woodhouse's toad (*Bufo woodhouseii*) has a large range encompasses the Great Plain states, as well as Utah, and western Colorado. Disjunct populations occur in portions of Idaho, eastern Oregon and Washington, and the Southwest. This species occurs in BICA, near the western edge of its range in Wyoming.

Physical Descriptions

Tiger salamander adults have a long body with 4 stout limbs and a tail, they are thus more similar in general appearance to lizards than to frogs and toads. Adults range up to about 9 inches long, including the tail. Color is variable, from light olive or brown to nearly black, often with yellow blotches or streaks on the back and sides. The skin is smooth. Eyes are prominent, protruding from the broad head above a wide mouth. Salamander larvae, which cannot live out of water, have a uniform dull color and large feathery gills on both sides of the body just behind the head. Larvae range in size from less than ½ inch to 8 inches. The only salamander in the GYE, it is unlikely to be mistaken for any other amphibian species.

Boreal toads have a wide, stocky body, short limbs, and a blunt nose. They are brown, gray, or olive green with irregular black spots and a white stripe down the length

of the back. The skin has large, numerous “warts”. In juveniles, the warts are often reddish in color. There are prominent, oval glands behind each eye. Size ranges from less than 1 inch (newly metamorphosed toadlets) to about 4 inches long. Toad tadpoles are usually black and often congregate in large, conspicuous groups in shallow water. In late stages of development and on some individuals, the color lightens and they may be confused with Columbia spotted frog tadpoles. On the underside, belly pigment usually conceals the intestines of boreal toads, unlike spotted frog tadpoles. The stocky, wide body shape and white stripe on the back serve to easily distinguish boreal toad adults from other amphibian species in the GYE.

Boreal chorus frogs are the smallest adult amphibians of GRYN; maximum size is about 1.5 inches, and male frogs are usually smaller. They come in a variety of colors: brown, olive, tan, bright green, or bi-colored (with the back a different color than the sides). Three dark stripes run down the back, often incomplete or broken into blotches. A black mask extends in a stripe from the snout through the eyes and down the sides. The skin is smooth. There are tiny pads at the tip of the toes. Males have an inflatable throat. Tadpoles are brown or greenish, with a metallic sheen. The eyes are placed toward the sides of the head and protrude in profile when viewed from above. Chorus frog tadpoles are reliably distinguished by their protruding eyes. Chorus frog adults can be distinguished from small-sized spotted frogs by their smooth skin.

Columbia spotted frogs come in a variety of dull colors: gray-brown, dark olive, tan, or greenish. The back, sides, and legs have irregular black spots, often with light-colored centers. Spots may be poorly visible on dark individuals. The skin is always bumpy, even on very young, small frogs. Many but not all adults have brilliant salmon color on the underside of the legs and belly. Spotted frogs have the classic frog appearance: long hind legs, webbed feet, and a rather pointy snout. They range in size from less than 1” after metamorphosis to just over 3” long. Males have swollen inner digits (“thumbs”) with a dark pad. In the GYE, visitors often mistake Columbia spotted frogs for leopard frogs. Adult spotted frogs differ from leopard frogs by virtue of their bumpy skin and irregular spots without light borders. Spotted frog tadpoles are dark in color after hatching but their color lightens to brown or greenish-brown, with gold or brassy flecks on the upper surface. The tail is often twice as long as the body. Spotted frog tadpoles at some sites grow to over 3 inches in length, the largest tadpoles in the GYE (other than the non-native bullfrog tadpoles). They can usually be distinguished from boreal toad tadpoles by their light color, large tails, and nearly transparent belly skin, through which intestines are often visible. Leopard frog tadpoles would be difficult to distinguish.

Northern leopard frogs have a smooth skin, dark brown

to green in color, with distinct spots that have pale borders. Spots may be less conspicuous on young frogs. Undersides are white. Conspicuous, light-colored folds extend down both sides of the back. The tympanum is obvious and about the same size as the eye. Maximum size is about 4 inches, but most adults are smaller (< 3 inches). The smooth skin and distinct, haloed spots serve to distinguish leopard frogs from Columbia spotted frogs. Tadpoles are dark brown, olive or gray. The tail fin is usually less than the body length. The belly has either silver blotches or is transparent enough to see the intestines. Tadpoles may be difficult to distinguish from Columbia spotted frog tadpoles.

American bullfrogs are dark green, olive, or brownish-green, mottled with black spots on the back and snout, and with black bands on the legs. The underside is cream to yellowish, with gray mottling. The tympanum (ear drum) is as large as or larger than the eye, and partially surrounded by a ridge or groove that extends to the shoulders. Adult bullfrogs are the largest frogs in the region; they can reach lengths of 8 inches. Juveniles are of course much smaller, about 2 inches. Large tympanum, lack of dorsolateral folds, large size, and bellowing call distinguish this species from other frogs. Tadpoles are olive-green with numerous black spots. The body is long and arrow-shaped; the tail trunk is massive. They can grow to a length of 4.5 inches, much larger than other tadpoles of the region. Black polka-dots and the shape of the tadpoles are distinctive when compared to other tadpoles of the region.

Plains spadefoots are named for the hard, dark, wedge-shaped “spade” on both hind feet, used for digging. They are brown or gray with darker mottling and a white belly. The back, often covered with small tubercles tipped in yellow or orange, may have 4 light stripes with the middle pair forming an hourglass shape. The body is round and small; maximum size of adults is less than 2 ½ inches in length. The short snout is said to resemble a pug dog in profile. Pupils are vertical in bright light. There is a hard lump between the eyes. Plains spadefoots resemble Great Basin spadefoots but have only a slight potential for range overlap in Wyoming. Tadpoles are light in color, sometimes with a bluish iridescence. The body has a globular shape. Eyes are dorsal. The belly is iridescent gold, and the gut coil is usually not visible through the skin. Oral papillae completely encircle the mouth. On some tadpoles, jaw muscles are huge and bulge from the sides of the face.

Woodhouse’s toads are gray, brown, or olive green with small pale spots or blotches. A conspicuous light line runs down the center of the back. Males have dark throats. Adults have dry skin with many small warts. Adult body length is 2.5 to 5 inches. There are prominent, oval parotoid glands behind the eyes. On the top of the



head between the eyes are two parallel protuberances called cranial crests; these connect at a right angle behind the eyes, like 2 L's placed back to back. These parallel crests distinguish Woodhouse's toads from boreal toads. Tadpoles are similar to the boreal toad.

Ecology

Habitat

Amphibians are generally found in wetlands throughout most habitat types encompassed by the parks of the GYE, except those at the highest elevations (e.g., alpine tundra). In BICA, which is a more arid environment, potential amphibian habitat is very limited. While the general habitat occupied by amphibians is broadly defined as any area with the capacity to hold standing water for all or part of the year, the species that occupy an area are closely linked to a variety of local characteristics. These include the depth and conductivity of the water, the amount of emergent vegetation in or surrounding a water body, presence of fish, and the suitability of upland sites needed for over-wintering, foraging, and seasonal migrations.

Ecological role

Amphibians play an important role as an indicator of the health of wetland ecosystems. Amphibians are sensitive to a variety of threats and, thus, can serve as early indicators of ecosystem change when monitored over long time scales. This sensitivity to numerous threats is one of the few downfalls of using amphibians as indicators of overall ecosystem health; it is often difficult to pinpoint the cause of declines. However, changes in amphibian populations can often be linked to one of the following causes, all of which suggest a decrease in overall ecosystem health: pollution, introduced species, drought, habitat destruction, disease and ultraviolet radiation. Amphibian populations may be affected by these factors and exhibit measurable changes in site occupancy, distribution, abundance, species richness, and increases in both disease occurrence and malformations. These changes in amphibian populations have cascading effects on other aspects of the ecosystem, such as predator, prey and competitor populations, energy flow, and nutrient cycling (Stebbins and Cohen 1995).

Life History

Tiger salamanders spend much of their lives underground but must return to water to breed. A variety of water bodies, usually without fish, are used for breeding and larval development. As larvae, tiger salamanders are carnivores, feeding primarily on zooplankton, aquatic

insect larvae, other invertebrates, and tadpoles. Adult salamanders feed on earthworms, insects and sometimes small vertebrates. Adult salamanders move from their over-wintering sites to breeding sites in the spring after snowmelt. The male salamander leaves a sperm-filled sack on the substrate of the pond, which the female picks up with her cloaca for fertilization. The eggs, deposited singly and attached to underwater vegetation, incubate for two to four weeks. Larvae sprout legs in a couple of weeks and grow quickly in warm water. Salamanders are capable of paedogenesis, wherein sexually mature larvae are capable of breeding before transforming into adults. It sometimes takes two or more years to transform into adults. Spectacular mass migrations of adult salamanders have been observed crossing roads in the GYE, particularly during rainy evenings.

Boreal toads hibernate in burrows in terrestrial environments, and are often found far from water bodies. A variety of aquatic habitats are used for breeding and larval development, usually characterized by high conductivity and acid-neutralizing capacity. Many breeding sites have a geothermal influence. Old oxbows and backwater channels associated with rivers are also used, and excavated sites such as old quarries and manmade ponds. Boreal toads prefer to eat ants, but also feast on moths, beetles, other insects and sometimes small vertebrates. Breeding migration occurs in May or June, when males congregate at breeding sites, waiting to grab arriving females in an embrace called "amplexus". Females extrude eggs in two long parallel strings, fertilized externally by the male toad. Toad tadpoles can occur in very large groups; the aggregations of these black-bodied animals warms the water and churns up food-laden sediments. Tadpoles develop rapidly and metamorphosis occurs at varying times, as early as mid-June at thermal sites, but as late as August or even September at some riverine sites. At major breeding sites, enormous numbers of toadlets can be observed as they emerge for dispersal away from the water.

Boreal chorus frogs hibernate near or below the ground surface; they are one of a few species of amphibians known to tolerate freezing during the winter. In spring, they seek shallow aquatic habitats with abundant emergent vegetation. After breeding, chorus frogs inhabit moist meadows or woodlands; unlike other members of the tree frog family, do not spend significant amounts of time in vegetation; rather, they prefer to stay the ground. Boreal chorus frogs eat ants, spiders, flies, beetles, aphids and other insects. Although chorus frogs are the GYE's smallest adult amphibian, they are by far the loudest. During breeding season, males congregate at breeding sites and produce ringing trills by inflating and vibrating vocal sacs. The choruses reach their peak in the evenings during May and early June. Females, summoned by the



calls, produce small clusters of eggs which they attach to stalks of vegetation just below the water surface. Eggs hatch within 10-14 days, and metamorphosis is usually complete by late July or early August. Despite their abundance, chorus frogs are not often seen by casual observers; tadpoles are shy and swift, while adults are tiny and cryptic. However, large numbers of recently metamorphosed froglets are sometimes observed as they emerge from ponds.

Columbia spotted frogs are closely linked to aquatic habitats and are seldom observed more than 50 feet from water bodies except during migrations. Hibernation occurs in or near aquatic sites, where the frogs can avoid freezing or oxygen depletion. A large variety of water bodies are used for breeding and larval development, but most have abundant emergent vegetation or woody debris that can be used for hiding cover. Spotted frogs eat a large variety of prey including insects, earthworms, mollusks, and even small mammals and tadpoles. Foraging occurs mostly during the day or evening, probably because cold temperatures limit their activities. In the GYE, male spotted frogs begin to breed when they are four years old, while females begin when they are five to six years old. While males can breed annually, females can only breed every other year due to the energy expense of producing eggs. Egg masses, probably one clutch per female, float on the pond surface shortly after deposition. In the GYE, each spotted frog egg mass contains 200 to 800 eggs. Females often deposit egg masses in close proximity to each other, resulting in large clusters covering several square yards of pond surface. Hatching occurs in one to three weeks. Time to metamorphosis, about 6 to 12 weeks, is strongly influenced by water temperatures, with tadpoles at warmer sites developing more quickly. After transformation and emergence, the young frogs migrate overland to suitable wintering sites. Adult spotted frogs also migrate annually among breeding, foraging, wintering sites; these migrations sometimes involve long movements (e.g., more than 1500 feet) over dry land (Patla and Keinath 2005).

Northern leopard frogs hibernate in aquatic habitats, typically with deep, cold water. Breeding occurs in seasonal pools, ponds, or lake edges with dense emergent or aquatic vegetation. After breeding, adults occupy grassy meadows, marshes, riparian zones, and open woodlands. They feed on a large variety of invertebrates. Male leopard frogs call from breeding sites in spring, attracting females. The call is loud and variable, including chuckles, grunts, and snores. A few days after calling begins, females produce a single egg mass with hundreds or thousands of eggs; the egg mass is attached to vegetation just below the water surface. The eggs hatch within two weeks, and tadpoles transform into frogs by mid or late summer. Like spotted frogs, leopard frogs are capable of long overland movements. They are agile, fast frogs that can jump over 3 feet with one leap.

American bullfrogs occupy permanent ponds, reservoirs, or large deep marshes; they are often found in human-modified habitats. They over-winter at the bottom of water bodies. Their diet consists of just about anything small enough to be captured and swallowed; including invertebrates, amphibians, reptiles, small birds and mammals. Breeding occurs in warm water, and the breeding period may be extended over several months. Males defend territories, producing a loud, bellowing call from approximately May through August. Females deposit large numbers of eggs in a broad sheet of jelly that initially floats on the surface, and then slumps down onto aquatic vegetation. Tadpoles emerge after four days and can remain tadpoles for up to three years before metamorphosing, longer than any other frog in the region. Sexual maturity occurs when the frog is three to five years old. In the GYE, Kelly Warm Springs in GRTE is the only known breeding site. Expansion of this species to other sites in the GYE would be a cause for alarm because of the threat this species poses to native amphibians of the western U.S. Bullfrogs, much larger than native amphibians of this region, prey on and compete with native frogs, and their introductions may spread amphibian diseases.

Plains spadefoots are well adapted to live in dry conditions, spending most of their lives under the ground. They use the "spades" on their hind feet to borrow rear-end first into the soil. In winter, borrows may be 3 feet or more deep beneath the surface. While underground, spadefoots live off lipids stored in their bodies and extract water from the soil, relying on unique physiological traits to reduce water loss and mitigate its scarcity. Spring or summer rains stimulate the spadefoots to emerge. They congregate to breed in temporary pools, where males produce a brief, snoring call. After a few days, the adults disperse away from the pools. Eggs are attached to objects in the water, and hatch within a couple days. Larvae develop rapidly and may metamorphose in as little as 2 weeks, under pressure of the pool drying up. In some pools, the tadpoles become carnivorous, developing enlarged jaws and feeding on invertebrates as well as other tadpoles.

Woodhouse's toads are mostly nocturnal, but are sometimes seen during the day. Habitats include river valleys, flood plains, and agricultural areas. The species is relatively tolerant of disturbed habitats and takes advantage of human-created water bodies for breeding. A very large variety of invertebrates are consumed opportunistically. Attracted to roads for foraging, many toads are killed by vehicles in some areas. Woodhouse's toads over-winter underground and emerge in April or May to congregate in a large variety of breeding sites, just about any water body with a shallow margin and still water. Males have a long, shrill, nasal call. Eggs are laid in long strings, in single or double rows. Hatching occurs in a few days, and tadpoles require 4 - 7 weeks for development. The metamorphosis



emerge from the breeding sites at small size (½ to ¾ inch) but grow rapidly.

Status in the Greater Yellowstone Network

Threats

Chytridiomycosis: The disease chytridiomycosis is caused by a recently identified species of parasitic fungus (*Batrachochytrium dendrobatidis*), known as the amphibian chytrid fungus. Chytridiomycosis is viewed as a major threat to amphibians worldwide, causing population declines and species extinctions. This emerging infectious disease is thought to have originated in Africa, spreading rapidly since the 1970s (Australia Department Environment & Heritage 2006).

Amphibian chytrid fungus attacks keratin in the skin of amphibians. This water-dependent fungus spreads via free-swimming zoospores, which colonize amphibian skin and develop into zoosporangia. The fungus is thought capable of persisting in aquatic environments in the absence of amphibians. Amphibian larvae are not lethally affected, although they can carry the fungus in mouthparts and toe tips during later stages of development. Some amphibian species (including tiger salamanders and bullfrogs) can carry the fungus without being killed by it, and they may serve as vectors of the pathogen to more susceptible species.

The responses of amphibian populations infected with the fungus range from no perceptible impact to mass mortality events to severe decline without recovery. In the western U.S., chytridiomycosis is thought responsible for the decline of the boreal toad in the southern Rocky Mountains (Colorado and southern Wyoming), and the recent, catastrophic decline of this species in Rocky Mountain National Park. It has been implicated as the major cause of on-going decline of mountain yellow-legged frogs in California's Sierra Nevada. The disease may persist in healthy amphibian populations once an epidemic wave has passed through.

Chytridiomycosis was first detected in the GYE in 2000, on boreal toads of the National Elk Refuge in Jackson, WY. It is not clear what effect (if any) the disease has had or is having on amphibian populations in the region. On-going research in the GYE by researchers from Idaho State University and USGS has found that boreal toads have high prevalence rates (50%) of chytrid fungus on their skin. However, no mass mortality events attributed solely to this disease have been observed, and some individuals carrying the fungus are surviving from one year to the next (USGS 2005). Due to intensive research, new insights about this disease in the GYE are likely to evolve in the near future (Muths et al. 2006).

Ranavirus: The genus *Ranavirus* (family Iridoviridae) causes disease in amphibians, fish and reptiles. Amphibian ranaviruses are considered a global threat to amphibian populations due to their high virulence and rapid expansion in area with previously unexposed populations. Ranavirus has only recently been discovered; past outbreaks may have been wrongly diagnosed as bacterial infections such as red-leg disease.

Ranavirus is associated with mass mortalities in amphibians, particularly larvae and recently metamorphosed juveniles, with death rates reaching 100%. Death is thought to result from organ failure due to tissue necrosis and possibly from secondary bacterial infections as well. Ranavirus can be spread through infected food, water, human handling, introductions of fish and amphibians (e.g., released bait and pets), boats and fishing gear, carrier animals that were previously exposed and appear to be healthy, and by transient animals in the environment such as cattle, birds, invertebrates and other amphibians. This disease is thought to be particularly associated with disturbed or degraded habitats and high population densities. Susceptibility to disease may be influenced by many factors, such as chemical exposure and temperature.

Unlike chytridiomycosis, ranavirus has not been shown to cause local or species extinctions. However, because ranavirus outbreaks sometimes kill all or most of an entire year class in a population, the persistence of local amphibian populations could be threatened by episodic die-offs. Current research efforts in the U.S. have focused mainly on ranavirus complexes affecting tiger salamanders in western North America.

Lethal ranavirus infections have been found at multiple sites in the GYE since 2001. The virus was isolated by the USGS National Wildlife Health Center from dead amphibian specimens collected at various sites in the GYE (Patla and Peterson 2004). One of the outbreaks was particularly noteworthy because it resulted in a die-off of adult spotted frogs, whereas the vast majority of die-offs caused by this disease in North America affect larvae or recently metamorphosed amphibians.

Chemical contamination: Chemical contaminants include locally applied herbicides, pesticides, fertilizers, wastewater, fire suppressant chemicals, and unintended releases of sewage, fuels, solvents or other chemicals used for maintenance or construction. Amphibians may be exposed to chemical hazards through direct uptake from water or by ingestion of contaminants in soils, sediments and food items. Relative to other vertebrates, knowledge about effects of contaminants on amphibians is scarce. Because of their unique physiology and life histories (e.g., permeable skin and protracted development in aquatic environment), amphibians may be unusually susceptible to toxins. Environmental guidelines developed for fish and invertebrates are likely to be insufficiently protective. For



example, Birge et al. (2000) found that many amphibian species are more sensitive to metal and organic compounds than rainbow trout, but noted that US EPA gives little consideration to amphibians in the formulation of final chronic values for aquatic pollutants and water quality standards.

The variety and severity of sublethal effects indicated by controlled studies suggests the potential for contaminants to affect amphibian populations. Chemical stressors, even at levels well below toxic concentrations, influence the ability of amphibians to handle environmental stress. The interaction of physical and chemical stress is an important area of research for amphibian population declines. Virtually nothing is known about actual exposures, risks, or effects to amphibians in the GYE from locally applied or accidentally released chemicals.

Airborne dispersal of contaminants may be an important contributing factor to amphibian declines in protected areas of the western US (Stebbins and Cohen 1995). Recent research indicates that declines of the California red-legged frog are related to the amount of upwind agriculture. Frogs in Yosemite and Sequoia National Parks and at sites near Lake Tahoe have detectable concentrations of pesticides and depressed cholinesterase (ChE) levels, which indicate exposure to organophosphates pesticides. Pollution from coal burning power plants is also a concern.

Ultraviolet (UV-B) Radiation: Because pollutants have reduced the thickness of the protective ozone layer in the atmosphere, increasing amounts of UV-B are reaching the earth surface. UV-B levels have increased an estimated 5-10% per decade since 1979, especially at higher latitudes and in early spring. Amphibians may be more vulnerable to harmful effects of UV radiation than other kinds of animals due to their naked skin (no scales or feathers) and shell-less eggs. Adverse effects of UV-B include interference with intracellular functions, impaired transcription of DNA, and interactions with chemicals that make them more toxic. Field and laboratory studies have demonstrated increased mortality, deformities, and susceptibility to fungal disease. These findings lead to claims that UV-B was the likely cause of some observed amphibian population declines, but this conclusion has not been widely accepted by amphibian researchers in the western U.S. These researchers point out that most amphibian species have adaptations to mitigate UV-B effects: enzymes that repair damage, protective skin pigments, and behavior or habitat selection. In Glacier National Park, the distribution of boreal toads shows no indication that UV-B is a limiting factor for breeding populations (Hossack et al. 2006).

Despite the debate over whether or not UV-B is a main factor in currently observed amphibian declines, researchers share concern about ozone depletion and the consequences of increasing levels of UV-B. Of particular concern is the potential for UV-B to interact in complex

ways with contaminants, climate, and disease. UV-B breaks down chemicals in the environment, sometimes producing more toxic substances. Simultaneously, it increases the sensitivity of exposed animals to contaminants and interferes with their immune systems. Possible consequences of UV-B radiation on amphibians include: reduced larval population size; malformations; higher rates of mortality when populations are stressed by drought and/or exposed to disease and contaminants; and amphibian population declines, particularly at higher elevations and in certain water bodies where mitigating factors such as the amount of dissolved organic carbon are reduced.

Invasive Species (New Zealand Mud Snail): The New Zealand mudsnail (*Potamopyrgus antipodarum* [NZMS]) is believed to have been imported from New Zealand to a hatchery on the Snake River in Idaho in 1986 and from there disseminated in the US through trout stocking. NZMS has been found in Lake Ontario, in the Columbia, Missouri and Colorado watersheds and, since 2000, in California (Owens, Mokelumme and Calaveras drainages). It is rapidly spreading throughout the western US. Wading anglers are thought to be a primary vector. In 1994, NZMS were found in the Madison River in YELL near the park boundary, and later in the Firehole, Gibbon, Gardner and Snake Rivers. Polecat Creek in the JODR has a particularly heavy infestation. Baseline studies indicate that the NZMS is spreading rapidly in some water of the park, with humans as the suspected vector.

NZMS often reach very high densities (e.g., >100,000/m²) in suitable habitat and up to 750,000/m² in sections of rivers in Yellowstone National Park (Koel et al. 2004). Because of this high biomass, NZMS pose a threat to aquatic ecosystems. In Polecat Creek (JODR), Hall et al. (2003) found that NZMS consumed nearly all primary production in the highly productive stream and dominated the nitrogen cycle. NZMS frequently comprise over 95% of the invertebrate biomass in a river, and there is much concern about impacts to native invertebrates, fisheries, and aquatic communities.

We hypothesize that larval populations of amphibians could be stressed, reduced or eliminated by food shortages and crowding if NZMS heavily infest amphibian breeding sites. The loss of important source areas for amphibian reproduction could result in amphibian population declines. If NZMS favor areas with a mild geothermal influence, boreal toads (which often breed in such areas) could be most at risk. Adult amphibians could also suffer from food shortages if invertebrate prey populations are reduced by NZMS.

Roads and Development: Roads and development (e.g., buildings, parking lots, campgrounds, maintenance staging areas and gravel pits) have direct effects on amphibians via mortality and effects on amphibian habitat. Potential habitat effects include wetland destruction and



modification, vegetation changes, and surface disturbances that render areas uninhabitable. In addition, development may serve as a source of contamination from road run-off, releases of hazardous substances (e.g., inadvertent spills, use and release of household or maintenance chemicals), sewage spills and wastewater, pest control and herbicide applications.

Many studies have depicted high rates of amphibian mortality on roads. Amphibian populations are most susceptible to high rates of road-kill when migrating en masse between habitat patches. Reduced anuran density and population abundance, lower probabilities of occurrence, and adverse population genetic effects have been attributed to roads.

Habitat alteration is the best documented cause of amphibian population declines. Declines in both the numbers of amphibian populations and in species diversity have been attributed to development. The destruction of wetlands removes breeding sites and fragments populations, making amphibians more vulnerable to regional extinction. Human-caused transformation of habitat can disrupt population connectivity, diminishing the rate of dispersal and recolonization, such that local populations are unable to persist through natural catastrophes or population fluctuations. Development can negatively affect habitat in two general ways: (1) by destroying sites or modifying their qualities; and (2) by creating barriers or hazardous zones between important habitat features.

Drought: Amphibian populations are sensitive to fluctuations in the amount and timing of precipitation. Drought has been implicated as the cause of drastic declines in frog populations. In addition to direct effects on survival and reproduction, drought can adversely affect amphibians by interacting with other factors, such as disease, ultraviolet-B radiation and exposure to contaminants. Although drought is a natural phenomenon, climate changes including drought could be occurring faster than organisms can adjust. Climate change is cited consistently as one of the main potential causes of amphibian population declines. Temperatures have increased 0.8° C in the West since the 1950s, and are forecast to rise between 2°C and 5°C in the next century (Hansen et al. 2001). Forecasts for trends in precipitation are highly uncertain, but earlier snowmelt dates mean that less water is available in mountainous habitats during summer, a factor that is likely to affect amphibian breeding success.

Drought adversely affects all amphibian species that occur in the GRYN because of their dependence on pooled surface water for reproduction. When a breeding pond dries up prior to the onset of metamorphosis, the entire reproductive effort for the year is lost. At ponds reduced in size because of drought, an increase of larval density can negatively influence larval survival by slowing

development. In addition, pond drying can result in early metamorphosis, which is linked to small body size and decreased survival rates in juvenile frogs.

In the GYE, most amphibian breeding habitat probably occurs in non-permanent water bodies, which may dry up or shrink dramatically during periods of below-normal precipitation. In drought years, particularly if such years occur consecutively, non-permanent amphibian breeding sites can become completely unavailable. Post-metamorphic amphibians, which use terrestrial habitats for non-breeding activities, also can be adversely affected by drought. The loss of body water through evaporation must be offset through absorption of water from wet or moist substrates. Amphibians must rehydrate frequently; death results from desiccation. Amphibians crowded into limited habitat also may be more subject to disease or parasite epidemics.

Status

None of the amphibian species in GRYN are listed as federally threatened or endangered. Several species are listed as species of concern in Wyoming: boreal toad, northern leopard frog, and Columbia spotted frog. These same species are also considered as sensitive species by USDA Forest Service and Wyoming BLM (Wyoming Natural Diversity Database).

Management Activities

Surveys for amphibian and reptile occurrence in the parks of the GRYN have been conducted since the early 1990s, with increased efforts since 2000 due to collaborative support from the USGS Amphibian Research and Monitoring Initiative and the NPS Inventory and Monitoring Program. The GRYN inventory project (2000-2003) identified a total of 10 amphibian and 18 reptile species in the parks (Patla and Peterson 2004). Amphibian occurrence was identified as a GRYN Vital Sign in 2004. The long-term monitoring program, implemented in 2005, seeks to determine amphibian population trends by assessing occupancy in a set of randomly selected watersheds in YELL and GRTE. It also entails site-specific monitoring of all previously identified boreal toad populations. Monitoring should also yield information on amphibian diseases and wetland trends, suggest what research is needed, and indicate what management actions may be needed to conserve amphibian populations. The GYE monitoring program is jointly supported by USGS and NPS, and implemented through Idaho State University. A separate monitoring effort was designed for BICA at the Yellowtail Wildlife Management Area, where most of BICA's amphibian habitat occurs.



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