

Science

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"Science affects the way we think together."

Lewis Thomas

Engineering a Future for Amphibians Under a Changing Climate



Matt Kluber

The coastal tailed frog belongs to the most primitive frog family on Earth. It breeds in Pacific Northwest streams, and its life history is closely linked with climate. Amphibians such as this one may have some innate resilience to some aspects of climate variation, but their current distribution is limited and may become fragmented by other stressors.

"It is not a sentimental but a grimly literal fact that unless we share this terrestrial globe with creatures other than ourselves, we shall not be able to live on it for long."

—Joseph Wood Krutch

After enduring some 400 million years on Earth, amphibians are disappearing around the world. Population declines and extinctions among their ranks have been rising steadily in recent decades. Currently as much as 40 percent of the roughly 6,300 known amphibian species are threatened. Researchers attribute these alarming losses

to many factors, including habitat loss, pollution, and disease. As these forces continue to take a heavy toll on frogs, toads, caecilians, salamanders, and their kin, emerging stresses brought on by climate change are pushing struggling populations into further peril. More variable climate patterns are already altering patterns of precipitation and temperature, shifting seasons, and delivering surprise freezes and warm-ups that can wreak havoc on landscapes and within biological communities. Devising strategies to forestall threats to the natural systems upon which amphibians depend poses daunting and—where rare species are concerned—urgent challenges. On an international level, the World Conservation

IN SUMMARY

Threats to the survival of amphibians, such as disease and habitat loss, are exacerbated by climate variation. Yet, many existing species- and land-management plans give little if any consideration to climate impacts. Moreover, many management actions that do address emerging climate patterns have yet to be evaluated for feasibility and effectiveness. To help address these needs, research ecologist Dede Olson and her colleagues compiled an array of novel management actions from around the world that aim to mitigate climate change effects on amphibians.

One set of approaches focuses on helping vulnerable species endure weather extremes by establishing or improving refugia such as riparian buffers and maintaining ponds by using artificial wetting systems, and providing logs and other shelter microhabitats. Another approach involves restoring riparian and wetland sites and improving connectivity between habitat "islands." A third strategic avenue entails using hydrological engineering to retain amphibian-friendly water levels in ponds, streams, and lakes. To stimulate further advances in effective management interventions that benefit amphibians and to facilitate global networking among conservationists, researchers have launched a Web site for building an online knowledge bank.

Union's Amphibian Conservation Action Plan identifies general management strategies for amphibians in response to climate change. Yet to date there are few instances of local and regional conservation programs that incorporate specific measures to apply these recommendations. However, an international workshop on amphibians and climate change held in Australia in 2009 has become a springboard for global cooperation on behalf of the beleaguered animals. Playing a leading role in these efforts is Dede Olson, a research ecologist with the Pacific Northwest Research Station. Not only has Olson helped to foster adaptation management practices for amphibians regionally, but she is working to establish an online knowledge bank and facilitate global networking among amphibian conservationists.

"From a conservation viewpoint, there is a spectrum of animal occurrences to consider, from common to rare species," she says. "Different management approaches are appropriate along this gradient. Most species aren't



KEY FINDINGS



- Installing microclimate refugia has proven to be a successful strategy for increasing breeding success and helping amphibians survive the stresses of high temperatures and excessive dryness.
- The development of varied habitats and restoration of pond networks has been shown to expand amphibian habitat across broad landscapes and stem population declines for some species.
- Hydrological engineering techniques to retain critical water levels on the landscape have allowed populations of some vulnerable species to rebound.

endangered, but we want to keep their populations thriving, which calls for landscape-scale actions. But those rare species living on the edge may well require special attention, on smaller scales, to remain viable."

In 2011 Olson and colleagues published a world-scale synthesis of potential engineering solutions for lessening climate effects and restoring and retaining amphibian popula-

tions. They focused on practical steps with low cost and high effectiveness. "Many of these schemes have been applied in restricted circumstances, and have yet to undergo rigorous, long-term monitoring to determine their effectiveness," she notes. Her hope is that shining a spotlight on novel ideas will inspire further study and enlarge the conservation toolbox for amphibian conservationists throughout the world.

A FOOT IN WATER, A FOOT ON LAND

Most amphibians need both an aquatic and a terrestrial environment to complete their life cycle. Water (or at least moist conditions) is required for laying eggs and metamorphosing from a juvenile, water-breathing form to an adult, air-breathing form. "Being tied to both water and land makes them especially vulnerable to changes in both realms," Olson observes. "Because of

these characteristics and the permeability of their skin—which is their respiratory organ—amphibians are highly sensitive to environmental change. The effects of chemical and other environmental changes frequently show up in amphibians first, so they serve as ecological indicators—the proverbial 'canaries in the coal mine'."

Moreover, amphibians occupy vital nodes in ecosystems. Individual species are often

"nested" in food webs, acting as both predators that feed on small invertebrates, and prey for birds and mammals. Thus, declines in amphibian numbers may either reflect or produce shifts in other animal populations.

The conservation approaches highlighted by Olson and her colleagues account for the life histories of amphibian species and their ecological roles.

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Nicola Mitchell

Keeping breeding sites moist for longer periods may help water-stressed amphibians. Researchers are using portable irrigation sprayers to manipulate moisture levels at breeding sites for a vulnerable terrestrial toadlet in South Australia.

MICROHABITAT AND MICROCLIMATE REFUGIA

Many amphibians of temperate and desert landscapes face growing threats as the availability of seasonal water becomes more variable. “During dry years, lakes, ponds, and streams can dry up quickly and prematurely. This can cause massive egg mortalities or wipe out tadpoles before they can metamorphose, sometimes dooming an entire cohort of a population,” Olson says. For example, in 1989, following years of below-average rainfall, an estimated half-million eggs of the Western toad were left high and dry on the receding shoreline of Lost Lake, Oregon.

The outcome can be especially injurious to vulnerable species that face multiple stresses, such as the Oregon spotted frog, whose pond habitats have shrunk as beaver have declined, among other factors. “Of course, wet years are also part of the boom-and-bust life cycle to which many amphibians have adapted, but in many places more busts are now occurring and the animals may not be resilient to persistently dry conditions,” Olson says. Species with restricted ranges that rely on seasonal waters may be particularly at risk.

Some wildlife managers experimenting with ways to keep moist habitats available during critical seasons have met with success. In South Australia, conservationists are employing portable irrigation sprayers to water known breeding sites for a vulnerable species of terrestrial toadlet—a relatively simple intervention that has significantly boosted their egg-laying. It’s a technique that could potentially help other water-stressed amphibians, such as terrestrial breeding frogs in Central America that suffer population crashes during periods of drought, and the frogs’ extended community would benefit as well.

Artificial misting also could potentially help reduce water stress for amphibians in high-elevation rainforests where cloud cover is predicted to diminish, Olson adds, but the concept hasn’t yet been scientifically tested. “In many places, steps to physically redistribute water—such as collecting and storing water during wet seasons and releasing it to critical habitat during dry seasons—will likely be needed to provide ‘lifeboats’ for rare species,” she says.

Across the landscape, a range of amphibians seek refuge from excessive sunlight exposure and high temperatures in downed wood, leaf litter, rock crevices, burrows, and other shelters. Numerous studies from various locations suggest that augmenting such microhabitats, especially on managed lands where such debris may be scarce, can boost



D.H. Olson

In 1989, the receding shoreline of Lost Lake, Oregon, left an estimated half-million Western toad eggs high and dry after several years of below-average precipitation. More mass-mortality episodes are projected in many areas due to changes in seasonal weather patterns.

amphibian survival and benefit invertebrates and small mammals as well.

Some lessons learned from efforts to mitigate impacts on wildlife from timber harvesting in the Pacific Northwest readily apply to adaptation management for projected climate change. Logging typically reduces the forest overstory, increases sunlight exposure and ambient temperatures, and diminishes the abundance of downed wood. These habitat

changes can challenge species adapted to the cool, moist conditions of mature forests.

Logs are particularly important for Northwest amphibians, as demonstrated in a 2006 study by Olson and colleagues on plethodontid salamanders in an experimental forest stand in the Oregon Coast Range. These salamanders comprise about a third of the region’s forest amphibian community. “As moisture decreases and surface temperatures rise with the



D.H. Olson

Streamside riparian reserves (left) with upland thinning (right) can retain cool, moist microclimates for amphibian habitats in western Oregon.

onset of summer, salamander activity declines. The animals appear to seek out progressively larger cover objects or retreat underground, so it seems they really benefit from access to a range of microhabitats,” Olson explains. The study revealed that during the peak of summer heat, log interiors remained cool enough to offer thermal protection. These and other findings indicate that providing logs of various sizes and accelerating the growth of large trees in coniferous forests may benefit amphibians in the face of temperature extremes. Similarly, in Costa Rican forests where declining numbers of dendrobatid frogs coincided with climate-induced reductions in leaf litter, researchers have shown that supplementing leaf litter resulted in more juvenile frogs.

The strategic placement of logs also may assist newly metamorphosed frogs leaving ponds and lakes to disperse across the land. For instance, managers with the City of Seattle’s Cedar River Municipal Watershed are experimenting with situating logs perpendicular to pond shorelines to provide sheltered exit routes from the water. Creating or enhancing riparian buffers (streamside vegetation) also provides cool, moist shelter for amphibians, as do pockets of shade from variations in topography. Research by Olson to select long-term



Sally Nickerson

In Seattle’s Cedar River Municipal Watershed, managers are placing logs perpendicular to pond shorelines to provide sheltered routes for young frogs leaving the water to disperse across the land.

management sites for the endangered Siskiyou Mountains salamander determined that the most promising habitat in its range lies on the

“dark sides” of ridgelines characterized by rocky substrates, abundant canopy cover, and north-facing slopes.

ADAPTIVE MANAGEMENT OF AMPHIBIAN HABITATS AT LARGER SCALES

Managing for microhabitats can naturally lead to broader habitat enhancements, such as manipulating ponds or pond complexes upon which entire populations rely. Plans for wetland restoration may focus on a key attribute of a single pond—for example, maintaining the appropriate water depth to meet species’ needs. Or, the aim may be to increase microhabitats over an extensive land area, as in Neotropical rain forests where biologists are installing artificial bromeliads and attaching breeding cups to tree trunks to assist bromeliad-breeding frogs.

At the other end of the spectrum are restoration designs of much greater scope and ambition, such as the Million Ponds Project in the United Kingdom and the European-Union-funded LIFE project in the eastern Baltic regions. These programs aim to reverse historical pond loss by creating an extensive network of wetland habitats.

Fostering such work in the U.S. and Canada are hands-on workshops for learning how to use low-cost, effective techniques for restoring wetlands. Taught by U.S. Forest Service wildlife biologist Thomas Biebighauser, the workshops have attracted wildlife biologists, hydrologists, engineers, public land managers, and participants from land stewardship groups. “Demand for this kind of expertise is



William Leonard

Torrent salamanders are associated with cold headwater streams in the temperate rain forests of the Pacific Northwest. Researchers with the Pacific Northwest Research Station are looking at how forest management can help retain the salamander’s habitat and required thermal regimes.

increasing in response to the decline of small wetlands from urban and rural development, concerns about invasive species, and changing climate,” Olson notes. Wetland restoration has long-term benefits not only for native amphibians but for other wildlife and native plants, as well as water quantity and quality.

Olson and her colleagues are particularly interested in cross-disciplinary outreach, so their synthesis also examined engineering innovations aimed at controlling the hydrology at conservation sites. Generally this

requires considerable technical expertise, and it often entails manipulating hydroperiods (intervals of time when water is present). For example, managers might excavate or reconstruct ponds and change vegetation patterns to extend the duration of wetness at a seasonal pond. A suite of such actions—as well as reestablishment of the North American beaver—is underway to promote water retention at key habitat sites for the Oregon spotted frog.

In another case, on a privately owned ranch in arid New Mexico, solar- and wind-powered

pumps were installed to tap into previously inaccessible ground water and fill constructed earthen ponds. For nearly two decades these artificial wetlands have served as a lifeline for local wildlife, including the threatened Chiricahua leopard frog. Today the site boasts the largest, healthiest population of leopard frogs in New Mexico.

An emerging threat to amphibian survival, chytridiomycosis, is widely considered the worst infectious disease ever recorded among wildlife. Since the 1960s chytrid, which is caused by a fungus, has spread to frogs around the world. “In about half the places that researchers are looking for the fungus, they’re finding it,” Olson says. “But it’s not everywhere in frog habitat, and where it’s present it doesn’t necessarily affect all the animals in a population.” The role of climate change in the spread of chytrid is a matter of debate. However, “It’s an aquatic fungus that grows optimally in cool, moist conditions. And the relative warming of high-latitude areas predicted by climate change models could favor the expansion of its range,” she warns.

In association with colleagues at Imperial College in London, Olson coordinates a global mapping project that tracks the incidence of chytrid and compiles data on the species affected. Their research addresses the conditions that can affect chytrid occurrence, including its association with climate parameters.



LAND MANAGEMENT IMPLICATIONS



- Innovative strategies to reduce the effects of climate variation on amphibians apply more broadly to co-occurring animal and plant communities. Thus the online knowledge bank and burgeoning toolbox of management interventions may prove valuable to a variety of managers.
- Because the plight of many rare amphibian species is critical, “time is of the essence” in acting to prevent their further decline or even extinction. The new online hub will facilitate rapid communication and collaboration among scientists, managers, and the public, saving time and improving designs for further testing.
- By encouraging global communication and participatory research on amphibians and climate variation, the Web portal will serve to provide scientific rigor to designed studies and quality assurance as trial-and-error approaches are shared.



Carter Kruse

A wind- and solar-powered pump system is used to maintain the water level in a constructed pond in New Mexico. The pond benefits a host of wildlife species, and provides essential habitat for the threatened Chiricahua leopard frog.

BUILDING AN ONLINE KNOWLEDGE BANK

Olson is convinced an altogether different kind of engineering approach—one utilizing global online connectivity—has a critical role to play in amphibian conservation. To this end, she has set up a Web portal as a hub for participatory research in cooperation with Partners in Amphibian and Reptile Conservation, (PARC). “It’s really important to create an international community,” Olson says. “We’re inviting researchers and managers from around the world to submit their ideas and report on their projects. We want to move beyond trial-and-error conservation by stimulating scientific exchange on design studies and the development of standardized methods for monitoring the effectiveness of various solutions over time. There’s as much to learn from the failures as from the successes.”

The fledgling Web site showcases promising strategies and other materials that aim to inspire conservationists to experiment and adapt incoming ideas to their particular situations. While the main focus will be on low-

cost, practical approaches for manipulating the environment, information is also being compiled on stop-gap conservation measures for rare species, such as the relocation of gravely threatened populations, captive breeding in zoos, and so forth. “These approaches are part of the larger toolbox, but they are often very costly and result in the mortality of precious rare animals, so it’s important to convey the lessons learned from such efforts,” Olson says. The strategies to reduce the climate effects on amphibians have broader application to co-occurring animal and plant communities, so the knowledge bank should prove valuable to a range of managers, she adds.

At the end of the day, Olson says, she is cautiously optimistic about the future of amphibians. “They have been with us for millions of years and have persisted through many changes, so I feel there’s hope. Some rare species are going to be lost. But many other species can persist with relatively little effort on the part of humans. However, we’re going to have to manage their habitats to address threats and

improve our understanding of their needs so we can help them survive. If we humans put our minds to it, we can do this.”

“There is quite a lot left.”

— Carl Safina

FOR FURTHER READING

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