Scientist Profile

Photo: Karen Pope

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"Most of my work for the USDA Forest Service has been devoted to Wilderness areas," says aquatic biologist Kathleen Matthews. "I have always been fascinated by natural environments, especially the Sierra Nevada and marine systems."

Studying the effects of cattle grazing on golden trout in the Golden Trout Wilderness, Inyo National Forest, was one of Matthews' first projects when she began working for the USDA Forest Service as an aquatic ecologist in 1992. Her research examined golden trout habitat selection, movement patterns, and the effects of cattle grazing on stream channel morphology, spawning, and golden trout population structure.

Since then she has continued to work on improving the management of aquatic systems in the wilderness. Matthews specializes in finding solutions for better resource management through quantitative field research. During the past eight years, she has walked hundreds of trails throughout Kings Canyon National Park and the John Muir Wilderness, gathering tens of thousands of data points and putting together an accurate picture of the status of aquatic systems in the high Sierra. Her inspiration is the wilderness itself and the drive to provide the information necessary to manage it properly.

Matthews' initial research was on marine fishes. She completed postdoctoral studies at the Canadian Government Pacific Biological Station, British Columbia, where she studied lingcod and rockfishes. During her Ph.D. studies at the University of Washington School of Fisheries, she focused on rockfishes in Puget Sound.

For her M.A. degree, Matthews studied at Moss Landing Marine Laboratories, through San Jose State University, analyzing the movement of fishes on artificial and natural reefs in Monterey Bay. Her B.S. degree is in zoology from the University of California, Santa Barbara.

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fascinating animal makes it especially vulnerable to changes in the aquatic environment. "Unlike many frog species, whose tadpole stages last but a few months, the mountain yellow-legged frog spends up to four years as a tadpole," notes Matthews. Egg masses are laid in water, and even the adults are highly aquatic compared to other amphibian species, she explains.

During the last few decades, scientists around the world have detected a worldwide decline in amphibians. The global nature of the reduction both in terms of species and overall numbers led scientists to postulate that whatever was causing the decline was global in nature. Factors such as increased ultraviolet light penetration as a result of stratospheric ozone loss, pesticide contaminants, and habitat loss appeared to play a role, at least in some areas.

However, the decline of the mountain yellow-legged frog, whose native range only includes the high Sierra and a few Southern California locations, has a local cause.

Yellow-legged Frog Research Study Area

Writer Anne M. Rosenthal holds B.S. and M.S. degrees in Biological Sciences from Stanford University and a Certificate in Technical Writing from San Jose State University. A science writer based in the San Francisco Bay Area, she served as editor of *Jasper Ridge Views*, a publication of the Stanford University Jasper Ridge Biological Preserve, for ten years. Her articles have been published in *Scientific American* On-line, *Astrobiology Magazine* (NASA), and *California Wild* (California Academy of Sciences).

Unless otherwise noted, all photos taken by K. Matthews

What's Next

To restore the mountain yellow-legged frog successfully scientists need to know more about the frog's life history and the habitat requirements for each of its life stages. With this in mind, Matthews is currently focusing on the basic ecology of the mountain yellow-legged frog. Her research team is studying the species in national park areas where trout are less abundant and the natural ecosystem is relatively undisturbed. The scientists' goal is to understand how the frog interacts with its environment in a more natural state.

One aspect of Matthews' work is discovering how far the frogs travel. By tagging frogs with small electronic chips, the team can find individual frogs repeatedly. This helps the scientists follow the frogs' movements, define their home ranges, and determine how long the frogs live.

The Draft Conservation Strategy for Mountain Yellow-legged Frogs envisions a Sierra-wide plan to manage high-elevation lakes, with national and state agencies involved in returning many lakes to a natural fishless habitat. This approach would help protect many native species, including the mountain yellow-legged frog. Future research will include other amphibians in decline throughout the Sierra, such as the Yosemite toad, foothill yellow-legged frog, and red-legged frog.

Frog with pit transmitter tag

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High Sierra Ecosystems

The Role of Fish Stocking in Amphibian Declines

With a rich diversity of aquatic habitats, including deep lakes, shallow ponds, and rushing streams, Dusy Basin in Sequoia-Kings Canyon National Parks typifies the high Sierra ecosystem where mountain yellow-legged frogs usually thrive. Yet throughout the Sierra, aquatic ecologist Kathleen Matthews found entire water basins empty of these amphibians. Comprehensive studies showed that exotic trout caused the precipitous decline.

Naturally Fishless

Perched in glacial cirques and mountain meadows, thousands of high Sierra Nevada lakes reflect surrounding snow-covered peaks and cobalt skies of a seemingly undisturbed environment. Streams meander through flats, rush down hillsides, and cascade as waterfalls over hanging valleys. With snowmelt their source, these high Sierra lakes and streams are sheltered from many of the pollutants and human activities affecting waters at lower altitudes.

Additionally, most of the high Sierra is administered as Wilderness by the USDA Forest Service or USDI National Park Service. The mandate for management of high Sierra lands designated as Wilderness is preservation for future generations, with natural forces unconstrained.

Yet high Sierra aquatic ecosystems are by no means completely protected; in fact, the effects of a single human activity, fish stocking, have drastically changed these ecosystems. The impact is so extensive that certain species, such as the threatened mountain yellow-legged frog, are now completely absent from entire water basins where they formerly occurred in large numbers, says aquatic ecologist Dr. Kathleen Matthews.

While native fishes do inhabit a few high Sierra lakes and streams, the majority of high Sierra water bodies are, in their natural state, fishless ecological communities.

"These high-elevation aquatic ecosystems contain relatively few species in comparison to many other aquatic ecological systems," explains Matthews. The food webs are fortified by algae and zooplankton at the bottom and dominated by amphibian, reptilian, and avian predators at the top. Barring exotic introductions, these waters lack fish altogether.

Why are high Sierra lakes and streams naturally without fish? From two million to 15,000 years ago, Pleistocene-Age glaciers scoured the high Sierra of its soils and organisms. The steep stream gradients and waterfalls left in the wake of glaciation were difficult for colonizing fish to navigate, leaving both the waterways and glaciated cirques and basins, now filled with snowmelt, without fish.

Considering that the mountain yellow-legged frog survives the intense cold, heavy snowfall, and ferocious winds typical of harsh Sierra winters, it is highly adapted to the alpine environment. Still, the life history of this

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From Science...

Major Themes

Naturally Fishless: Barring exotics, the aquatic ecosystems of high Sierra lakes contain algae, zooplankton, aquatic vegetation, aquatic insects, amphibians, garter snakes, and aquatic birds.

Introduced Trout: 150 years of fish stocking introduced exotic species of trout into many of the lakes.

Research Results

Unequivocal Relationship: The presence of trout is definitively linked to a decline in mountain yellow-legged frog populations.

Effects Throughout the Food Chain: Trout presence also dramatically reduced numbers and distribution of Pacific treefrogs, mountain garter snakes, and large-bodied zooplankton.

Lakes are Resilient: Once trout are removed, lakes return to their initial natural state within 11 to 20 years, assuming there are frogs in the surrounding area and viable zooplankton egg banks.

An Era of Fish Stocking

As early as the 1850s, miners, sheepherders, and early settlers moved native species of trout into fishless high Sierra lakes and streams, seeking to supplement their food supply. Private groups and individuals, as well as government agencies, continued stocking fish—often exotic species not found in California—and by 1915, the eminent field zoologist Joseph Grinnell had observed the effect of these introductions.

Grinnell noted that in lakes where trout were stocked, tadpoles of mountain yellow-legged frogs were absent. However, at the time of Grinnell's surveys, trout introductions were still limited, and amphibians remained by far the most numerous land-based vertebrates in the high Sierra.

During the years that followed, stocking for recreational fishing accelerated rapidly and aerial stocking became widely used. The National Park Service limited stocking in Yosemite and Sequoia-Kings Canyon National Parks in the 1970s, terminating it altogether in the 1990s. But self-sustaining trout populations remained in many national park lakes, and fish stocking continued on Forest Service lands.

Alarming Amphibian Decline

Then, in 1994, a group of scientists surveyed areas where Grinnell had found mountain yellow-legged frogs early in the 20th century. The scientists' findings revealed a dramatic range contraction: Only 15 percent of the locations where Grinnell had recorded sightings still hosted the species. Certainly, a distinct change in high Sierra ecology had taken place. The next step was to determine the cause of the decline and whether other animals in the food chain were affected.

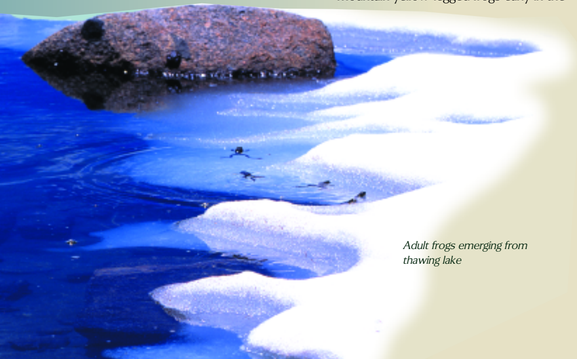
Beginning in 1995, Kathleen Matthews, working with Roland Knapp of the Sierra Nevada Aquatic Research Laboratory, University of California, and a field team of over 20 research assistants, undertook one of the most extensive field studies of the impacts of introduced fish conducted in the United States. The goal of their three-year study was to pinpoint whether or not trout were, in fact, affecting the native biota including mountain yellow-legged frogs. The scientists designed their fieldwork so that statistical analysis could be used to describe the extent of any effect in unequivocal, quantitative terms.

Trout—A Definitive Factor

The scientists compared 1,000 lakes in Kings Canyon National Park to a similar number in the adjoining John Muir Wilderness where the State had continued stocking practices. These National Park and Forest Service Wilderness areas had remarkably similar landscapes, and their aquatic ecosystems varied primarily by the percentage of lakes bearing trout.

The scientists analyzed their data from three perspectives—landscape, watershed, and individual water bodies. At all three scales, an increase in trout definitively correlated with a decrease in mountain yellow-legged frogs. When the scientists looked at each lake separately, accounting for habitat effects, the frogs were three times more likely to occur and six times more abundant when fish were absent.

The scientists were especially interested in lakes that were deep enough to neither freeze solid during winter nor dry up in summer. These lakes were used for stocking, and the scientists hypothesized



Adult frogs emerging from thawing lake

Aerial fish stocking

that the same water bodies were essential to the highly aquatic mountain yellow-legged frog. Results of the study supported this hypothesis, with the authors concluding that predatory trout now occupied the lakes where mountain yellow-legged frog tadpoles were found historically in the greatest numbers. The frogs, concluded Knapp and Matthews, were increasingly restricted to marginal and isolated habitats, their fragmented populations slowly becoming extinct.

Searching for emerging adult frogs

Strong Ecosystem Effect

In a separate study of the same 100,000-hectare area, Matthews and colleagues looked at whether the trout affected Pacific treefrog populations. The most abundant amphibian in western North America, this species does not have a prolonged tadpole phase that restricts it to deeper lakes and exposes it to predatory trout over an extended period.

Still, the results of the study showed a surprisingly strong effect. There was a major reduction in Pacific treefrogs where trout were present. For example, in Kings Canyon National Park, 26.6 percent of all water bodies contained Pacific treefrog larvae, as compared to 7.2 percent of those in the John Muir Wilderness.

Even more dramatic were the results of a mountain garter snake survey in the same lakes. This snake feeds on amphibians, including both the mountain yellow-legged frog and the Pacific treefrog. In Kings Canyon National Park the scientists located 62 garter snakes; in the adjacent John Muir Wilderness not one garter snake was found in the 1,044 lakes surveyed.

Additional studies showed that at trophic levels below the frogs, trout were clearing the lakes of larger zooplankton, fairy shrimp, and benthic (bottom) invertebrates.

Although the lakes had low resistance to the introduction of trout, with faunal make-up changing drastically in their presence, one of the studies revealed an exciting attribute of high Sierra lakes: they had a high level of resilience, reverting to their natural state once trout were removed.

Even where trout had drastically altered the fauna, lakes returned to near normal within two decades, with some lakes recovering in periods as brief as eleven years. The finding has important implications for restoration of alpine lake ecosystems, implying that simply by removing trout, at least some lakes can return to their original state.

The scientists conducting the study—Matthews and Knapp, along with Orlando Sarnelle of the Department of Fisheries and Wildlife, Michigan State University, East Lansing—attribute the recoveries to life stages that can travel to and recolonize lakes where trout have been removed. Adult stages of many benthic invertebrates are winged, scientists point out, and nearby populations of adult frogs are able to travel overland. Viable egg banks, a potential source of zooplankton, are also important.

Yet the scientists, while optimistic, wave a flag of caution. Conditions are changing rapidly, they emphasize, with frog populations quickly disappearing and zooplankton egg banks aging. "As time passes," Matthews says, "return to natural conditions becomes less likely without a higher level of intervention."

Although scientists initially speculated that amphibian declines resulted from global environmental factors, this research demonstrates that local causes, such as fish stocking, play an important role in some cases. While the designation "Wilderness" implies protection, fish stocking permitted on Forest Service Wilderness contributed to amphibian declines and major ecosystem changes, indicating that as currently defined, Wilderness does not offer complete protection to aquatic systems.

Biologist collecting plankton sample

Garter snake eating a mountain yellow-legged frog

...To Management

A Conversation with Kathleen Matthews

Q *Your research shows that exotic trout have affected high Sierra lake ecosystems at several trophic levels. Why is the ecosystem found in high Sierra lakes so vulnerable to introduction of a single species?*

In comparison to many aquatic ecosystems, the food web typical of high Sierra lakes is relatively simple. Therefore the introduction of even a single species—especially a top predator that consumes members of the food chain ranging from zooplankton to amphibians—has drastic effects.

Q *What are some of the key elements of a restoration plan for mountain yellow-legged frogs and high Sierra aquatic systems?*

Although the lands are managed by two national agencies, the USDA Forest Service and the USDI National Park Service, most responsibility for managing fish and wildlife rests with the California Department of Fish and Game. At present, this includes jurisdiction over fish-stocking practices for lakes situated on high Sierra national forest lands. Coordination between these agencies is absolutely essential to a successful restoration plan and management of threatened species.

Halting fish stocking will empty some lakes of trout solely as a result of attrition. In larger lakes, where exotic trout tend to be self sustaining, our studies show that fish can be removed by netting. These simple measures could reverse the decline of the mountain yellow-legged frog and gradually restore the natural ecology of high Sierra lakes.

Q *At this point entire basins lack frog populations. How could mountain yellow-legged frogs be restored to these regions?*

The restoration process has to start with removal of trout from many of the lakes. Introducing frogs into lakes with trout still present certainly would not be successful.

In frogless basins there are many considerations. For example, does it make sense to potentially harm a healthy population of frogs for restoration of other areas? And with several subspecies present, a nagging question is which populations are best adapted genetically for introduction into frogless basins. It is possible that these basins have lost subspecies of their own.

Q *What could the restoration starting point be?*

In some basins, as many as half of the lakes still retain mountain yellow-legged frogs. By gill netting trout from some of the frogless lakes, we could pave the way for frogs to return to more of the lakes in these basins. This could be the quickest way to enlarge and stabilize the populations of this threatened species.

Time is of the essence—restoration becomes more difficult as populations continue to erode.

Not Pristine: Due to fish stocking, high Sierra Wilderness aquatic systems are greatly altered.

Drastic Effects: Introducing even a single predatory species into an ecosystem can reverberate up and down the food chain.

Multiple Agencies: A successful recovery plan for high Sierra aquatic ecosystems requires cooperation between multiple state and federal agencies.

Simple Measures: Terminating fish stocking and netting trout from many of the lakes they now occupy could be sufficient to reverse the decline of mountain yellow-legged frogs in some areas.

Frogless Basins: Where mountain yellow-legged frogs are absent from entire basins, more complex measures are required to repopulate them.

Starting Points: Restoration in basins that still contain frog populations is the place to start.

Mountain yellow-legged frog with transmitter