# Non-Native Fish in Mountain Lakes: Effects on a Declining Amphibian And Ecosystem Subsidy

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**Water resources help support both native fauna and introduced fish in high mountain lakes. This study shows that a threatened native amphibian has better breeding success in lakes with fewer introduced fish, and that fish removals lead to more 'export' of aquatic insects to terrestrial food webs. Continuing work will address the effects of introduced fish on upland species that consume aquatic insects and amphibians.**

Historically, a significant proportion of California's high elevation wilderness lakes were fishless, providing habitat for native fauna that are predatory on insects, including amphibians, reptiles, birds, and bats. Now, trout have been introduced into the vast majority of mountain lakes for sport fishing, and studies have shown declines in the native fauna, especially amphibians and some reptiles, including the Cascades frog (*Rana cascadae)*, a state and federal species of special concern.

In order to assess the effects of fisheries management techniques on the distribution and abundance of fish, amphibians, emerging aquatic insects, birds, reptiles and bats, we have undertaken a multi-year study. Our experimental design compares 12 wilderness lakes subject to three different fisheries management techniques (continued fish stocking, cessation of stocking, and fish removal) to four historically fishless reference lakes. Our 16 study lakes are between 1920 to 2210 m in elevation, with depths ranging from 2.7 - 11.2 m. The lakes are grouped in four geographical blocks within which sites were randomly assigned for stocking suspension, fish removal, or continued stocking. There is one historically fishless basin in each block.

We collected pre-treatment data in 2003, then removed trout or suspended stocking in eight basins. In 2004 we quantified post-treatment populations of fish, Cascades frogs and other amphibians, aquatic insects, birds, reptiles and bats. We sampled lakes six times per summer. Amphibians and snakes were monitored via mark-recapture and visual surveys. Aquatic insects were sampled using benthic sweeps, insect emergence traps and sticky traps. Bats were monitored via acoustic bat detectors, and bird abundances were quantified using point-count surveys.

At the beginning of our study in 2003, large-bodied insects, frogs, and garter snakes (*Thamnophis sirtalis*) were all less abundant in stocked sites compared with historically fishless 'control' basins. Our surveys in 2004 showed a higher abundance of Cascades frog tadpoles and metamorphs in fish removal lakes and in lakes where stocking was suspended compared to stocked lakes (Figure 1). Aquatic invertebrates also showed signs of recovery in basins with fewer fish. We expect that frogs and aquatic insects will continue to recover in our 2005 field season. Such recovery will allow us to more conclusively assess the indirect impacts of fish on snakes, birds and bats.

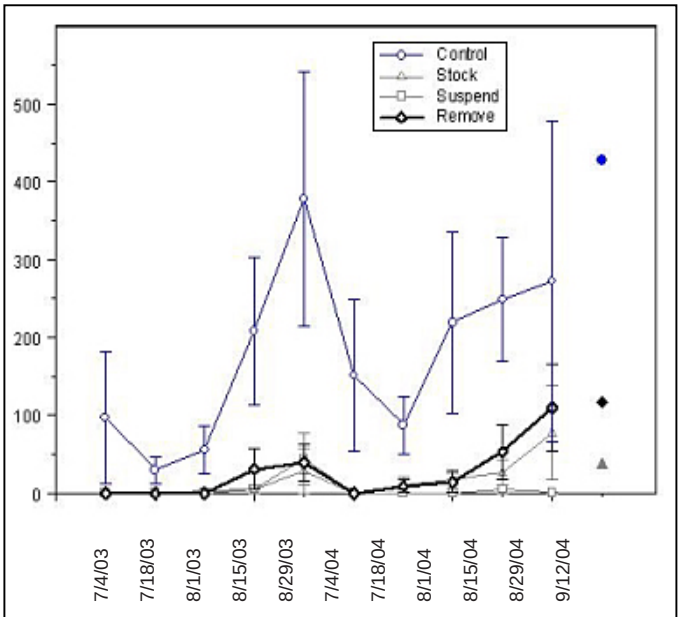


Figure 1. Mean number of larval Cascade frogs seen per survey period. The single points on the right of the graph indicate number of frog metamorphs.

Our work will be significant for the management of wilderness lakes in the Trinity Alps and elsewhere in California because it documents the responses of a wide variety of taxa to the introduction of fish via stocking. This information is vital to policy development for protecting and managing biodiversity in the extensive montane wilderness areas in the western United States. Information provided by this project will show whether adjustment of fish stocking practices could create landscapes where fish and frogs can coexist at broad scales.

In addition, this project has great relevance to developing ecological theory. Ecologists have recently recognized the importance of 'ecosystem subsidies', which are flows of nutrients and organisms across the borders between adjacent ecosystems, such as water bodies and terrestrial habitats. This study will show whether a predator introduced into one community affects the level of subsidy flowing into an adjacent community.

## ***Professional Presentations***

Pope, K. and S. P. Lawler. Introduced trout affect ecosystem subsidy and a threatened frog. Accepted abstract for 2005 Ecological Society of America Meeting, Montreal, Canada. August 8, 2005

## ***Collaborative Efforts***

Karen Pope, M.S., is the project leader. She is a graduate student in Ecology at U.C. Davis and an ecologist with the USDA Forest Service's Redwood Science Laboratory. This large-scale project was made possible by assistance from our granting agencies and the following people who contributed expertise, time and equipment to the project: Hartwell Welsh and the U.S. Forest Service Redwood Sciences Laboratory; Bernie Aguilar, Betsy Bolster and the California Department of Fish and Game.

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