Global food web alteration following goldfish introduction in palmate newt dominated pond ecosystem

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Freshwater ecosystems are central to the development and functioning of human societies and yet they are amongst the most altered worldwide. Alien species introduction is a leading cause of biodiversity loss in fresh waters, with impacts on recipient ecosystems that are recognized as some of the most significant, least controlled, and least reversible. Of particular concern is the replacement of strictly carnivorous apex consumers by omnivorous consumers because they can potentially have important and long-term impacts on biodiversity and ecosystem functioning by re-shaping food web architecture. In Larzac (Southern France), declining trends in palmate newt (*Lissotriton helveticus*) dominating ponds are correlated to goldfish (*Carassius auratus*) introductions. However, the processes leading to local extinction of newts are not fully understood. Additionally, despite being one of the most widespread fish introduced in Europe, goldfish impact on native ecosystems is poorly studied. Because they are omnivorous, goldfish may have a strong impact on the entire pond ecosystem, potentially making it an unsuitable habitat for newts. To assess the impact of goldfish leading to newt extinction, we compared community assemblage and food web structure of consumers in ponds naturally dominated by palmate newts and in ponds where newts have been extirpated following goldfish introduction, using various techniques including Carbon and Nitrogen stable isotope analysis in a Bayesian framework. Our results show that beyond direct interactions with newts, goldfish have profound detrimental impacts on the ecological communities of ponds by operating a global alteration of the food web on multiple trophic levels. Changes were characterized by a reduction in food chain length, trophic diversity and redundancy, and the extirpation of almost all exploitable resources available for newts. In the long-term, these changes likely explain newts' exclusion from invaded ponds and illustrate the complex detrimental effects of omnivorous species introductions for native ecosystems.

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