

>I SERV**Relationship between intraspecific diversity and ecosystem services: role of fish stocking practices****Métaprogramme BIOSEFAIR****Project report: 2024 - 2026**

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Intraspecific diversity is important for ecosystem functioning. However, it is strongly affected by human activities. For example, freshwater fish are subject to pressure from climate change, fishing, pollution and management practices such as restocking. These species support major ecosystem services, such as fish production, nutrient cycling and water quality. Changes in their intraspecific diversity could therefore have significant ecological and socio-economic consequences.

This project investigated the effects of Arctic char (*Salvelinus umbla*) restocking practices in peri-alpine lakes on the links between intraspecific diversity and ecosystem services. Restocking can alter intraspecific diversity, indirectly affecting fish biomass and nutrient cycling, which are important services for fisheries and water quality. Nonetheless, the links between fish management practices and ecosystem services remain largely unexplored.

The iSERV project aimed to (1) link intraspecific diversity resulting from restocking to the nutrient cycle (regulatory service) at the individual and ecosystem scales using a mesocosm approach; (2) quantify in situ the effects of restocking on genetic diversity and fish biomass production (production service); (3) quantify the local population's preference for char conservation strategies.

Studies conducted in Lake Annecy show that the current Arctic char population is highly dependent on stocking, as naturally reproduced individuals are very scarce. Fish from local fish farms and naturally occurring individuals had very similar genetic structures, growth rates and phenotypic traits, suggesting a close relationship between these origins. In contrast, fish from Lake Geneva fish farms were slightly genetically differentiated and showed higher growth rates. Despite contrasting stocking intensities, individuals from both fish farms contributed comparably to the population, indicating that the origin of stocked fish may influence their survival and contribution to total biomass, a key service for fisheries.

A common garden experiment revealed that functional differences depended on the origin and date of spawning of the fish, particularly in terms of zooplankton consumption and ammonium excretion, with contrasting thermal responses. These variations suggested that restocking could alter the nutrient cycle and trophic functioning of the lake, particularly in a context of global warming.

Finally, a mesocosm experiment showed that Arctic char influence the structure of aquatic communities through top-down effects on zooplankton and that differences between origins could alter the abundance of certain taxa present in the community. The overall effects on ecosystem functioning were moderate. Overall, the project highlights that restocking practices affect intraspecific diversity and, possibly, associated ecosystem services.

Detailed results

The main objective of the iSERV project was to assess the effects of Arctic char restocking practices on intraspecific diversity and associated ecosystem services, combining genetic, functional, experimental and socio-economic approaches. Overall, the work carried out is consistent with the initial objectives and has produced robust results, although the effects observed are generally small in magnitude but statistically significant.

Genetic and phenotypic analyses conducted in Lake Annecy showed that the current Arctic char population is mainly based on restocking practices, with individuals from natural reproduction being scarce. Fish from local fish farms and naturally occurring individuals were similar in their genetic diversity and phenotypic traits, suggesting that these practices have not led to a marked disruption of local intraspecific diversity. Fish from Lake Geneva were slightly genetically differentiated and distinguished themselves by slightly higher growth rates, which could influence their contribution to total biomass and fisheries production.

The common garden experiment testing functional differences, revealed differences in temperature responses depending on the origin and date of spawning of the fish,

particularly in terms of zooplankton consumption and ammonium excretion. These results suggest that, in a context of global warming, the choice of origin of fish used for restocking could modulate certain ecosystem processes, in particular prey abundance and the biomass of the char population in Lake Annecy.

The mesocosm study showed that Arctic char have a marked effect on the structure of aquatic communities through top-down mechanisms on zooplankton. The composition of zooplankton differed depending on the origin of the char populations. However, the overall consequences on ecosystem functioning (productivity, decomposition, physico-chemical parameters) remained relatively limited, confirming that the effects of intraspecific diversity, although real, were relatively weak at the ecosystem level.

The iSERV project shows that even when the effects of restocking on intraspecific diversity and ecosystem functioning are small, they can still be significant. The results highlight the importance of considering the origin of stocked fish, favouring origins that are genetically close to local populations in order to limit the risk of altering intraspecific diversity. The work also provides scientific evidence for adapting restocking strategies in the context of climate change, taking into account differences in functional responses between populations. Finally, integrating the perceptions and preferences of local stakeholders provides a solid basis for improving dialogue between scientists, managers and users, and for developing more sustainable and socially acceptable management strategies.

Scientific perspectives.

Several major scientific perspectives are emerging from this project. First and foremost, it appears necessary to conduct further research into the effects of restocking in high-altitude lakes, which are particularly fragile ecosystems, by carefully characterising the genetic and functional diversity of the introduced Arctic char populations and their evolutionary trajectories. In addition, the project has raised new questions about interactions between introduced species, particularly between salmonids and minnows, and their consequences for ecosystems. This research could build on the approaches developed in iSERV, combining functional responses, experiments and ecological modelling to better anticipate the medium- and long-term impacts of fish introductions.