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Eradication of introduced brook trout and recovery of alpine lakes in the Gran Paradiso National Park (Italy)

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INTRODUCTION

Why eradicating fish

Alien fish for recreational fishery have been introduced into **once fishless mountain lakes** worldwide, representing a major threat for biodiversity. Introduced fish are likely to survive in mountain lakes even if they are no longer stocked until an active eradication action is not implemented [1]

Non-chemical methods

Non-chemical eradication methods should be preferred to preserve non-target organisms, possibly including unique taxa which have evolved thanks to the island-like nature of mountain lakes [2]. Based on a few experimental studies [3,4,5,6], gill-nets (combined with electrofishing in inlets and outlets) demonstrated to be an effective restoration measure in invaded mountain lakes. The natural absence of native fish is a basic -but very rare in freshwaters- condition to apply mechanic eradication techniques without concern for native species [3].

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In the Gran Paradiso National Park (Western Italian Alps; Fig. 1), the impact of introduced brook trouts (*Salvelinus fontinalis*; Fig. 2) on biodiversity in high altitude alpine lakes was quantified [7,8], and was so strong as to lead the GPNP to undertake an eradication campaign, within the EU financed **LIFE+ BIOAQUAE** (Biodiversity Improvement of Aquatic Alpine Ecosystems) project. The **ecological resilience** of alpine lakes is monitored along with the eradication actions.

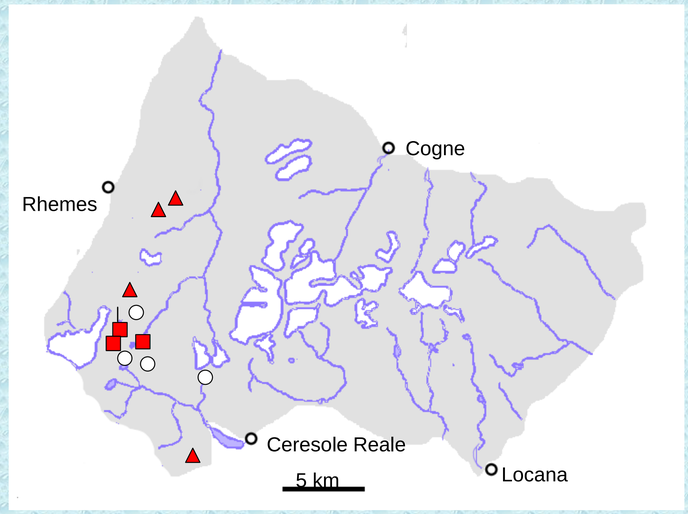

Fig. 1 Gran Paradiso National Park (Western Italian Alps) and studied lakes: naturally fishless control-lakes (white circles), stocked control-lakes (red squares) and "eradication" lakes (red triangles).

MATERIALS AND METHODS

Eradication

Intensive gill-netting and electrofishing have been used as eradication methods. The eradication started in June 2013 in three small lakes (depth range: 3-7.4 m) and one large lake (depth: 22.1 m). The nets have been left in the lakes for the whole duration of the project, including the ice-cover season (October-May). Eradication will be considered concluded after **one year without fish captures** [3].

Ecological resilience

The effects of the eradication have been monitored comparing the "eradication" lakes with a set of control lakes (both naturally fishless lakes and lakes still containing brook trout; Fig. 1) as a reference to quantify the **ecosystem resilience using several indicators** (hydrochemistry, water transparency, zooplankton and macroinvertebrate communities, emergent insects, and amphibians populations).

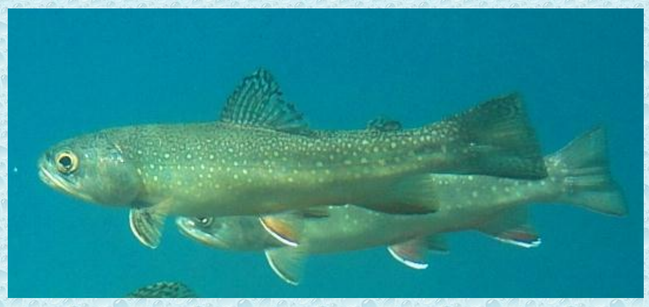

Fig. 2 *Salvelinus fontinalis* is native from North America and is widely used in mountain lakes stocking programs.

DJOUAN	DRES	NERO	LEYNIR
Area 1.3 ha	Area 2.6 ha	Area 1.7 ha	Area 4.5 ha
Depth 3.0 m	Depth 7.4 m	Depth 6.0 m	Depth 22.1 m
Total nets surface 922 m^2	Total nets surface 3120 m^2	Total nets surface 1148 m^2	Total nets surface 8027 m^2
1150 fish captured in the nets	2913 (+1297)* fish captured in the nets	201 fish captured in the nets	2950 fish captured in the nets
260 fish captured with electrofishing	6735 fish captured with electrofishing	0 fish captured with electrofishing	480 fish captured with electrofishing

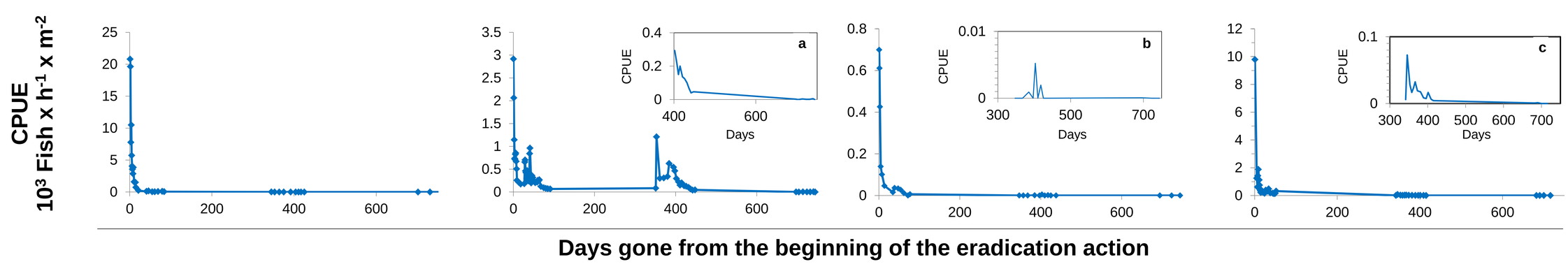

Fig. 3 Capture rates expressed as Capture Per Unit Effort (10^3 x Fish x h^{-1} x m^{-2}). The main morphometric data as well as the data concerning the capture efforts in each lake are provided. The points indicate the dates in which the fish have been removed from the nets. In lake Djouan the CPUE dropped down to 0 at the beginning of the second field season, while in the remaining lakes it decreased close to 0. To highlight the capture rates when fish density was very low (starting from day 300-400) we rescaled the Y axis of Panels a-c. * Some additive nets have been added in lake Dres to capture many fish hidden the littoral vegetation

RESULTS AND DISCUSSION

Successful eradication and satisfactory short-term resilience

In the course of the third field season, the eradication actions were successful in eradicating *S. fontinalis* from one small lake (Lake Djouan), while the fish population collapsed to values close to zero in the other three lakes. There are strong evidence of ecological resilience, with macroinvertebrates and *Daphnia* sp. being particularly sensitive to fish removal, but a longer resilience period is needed to understand the long-term ecological consequences of this restoration project. To the best of our knowledge, this is the first time that such an eradication program is successfully implemented in high altitude lakes in the European Alps.

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