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The impact of the introduced crayfish, *Procambarus clarkii*, on a lake community in Tuscany

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Abstract
We conducted a field experiment in a shallow oligotrophic lake in Tuscany to investigate the impact exercised by the non-indigenous crayfish, *Procambarus clarkii*, on mosquitofish fry (*Gambusia affinis*), snails (*Physa* sp.), and three aquatic macrophytes (*Nymphoides peltata*, *Potamogeton* sp., and *Utricularia australis*). The study showed that low and high densities of crayfish did not affect the survival of mosquitofish fry and *U. australis* but exerted a strong negative effect on gastropods and on *N. peltata* and *Potamogeton* sp. Therefore, the introduction of this crayfish species could represent a serious danger for the structure and the composition of the littoral zone communities of lentic aquatic habitats.

KEY WORDS: introduced crayfish / impact / lakes

Impatto del gambero esotico, *Procambarus clarkii*, su una comunità lacustre in Toscana
Un esperimento condotto in un piccolo lago oligotrofico in Toscana ha evidenziato l'impatto che la specie di gambero non-indigeno *Procambarus clarkii* esercita su avannotti di *Gambusia affinis*, molluschi (*Physa* sp.) e tre macrofite acquatiche (*Nymphoides peltata*, *Potamogeton* sp. e *Utricularia australis*). Lo studio ha mostrato che gamberi a bassa e alta densità non hanno effetti sulla sopravvivenza degli avannotti di *Gambusia* e su *U. australis* ma esercitano un forte impatto negativo su gasteropodi, *N. peltata* e *Potamogeton* sp. Di conseguenza, l'introduzione di questa specie costituisce un serio pericolo per la struttura e la composizione delle comunità litorali degli habitat di acqua lentica.

PAROLE CHIAVE: gamberi introdotti / impatto / laghi

INTRODUCTION

Crayfish constitute a large biomass in the littoral zones of several lakes, ponds and streams (e.g. ABRAHAMSSON, 1996). They are omnivorous species, omnivory having complex effects on the trophic interactions in aquatic communities (DIEHL, 1993; PRINGLE & HAMAZAKI, 1998). When an exotic crayfish is introduced in a new habitat, it may negatively impact biodiversity, as extensively shown in *Pacifastacus leniusculus* and *Orconectes limosus* (reviewed in NYSTRÖM, 1999). However, the impact of other non-indigenous crayfish, including the red swamp crayfish *Procambarus clarkii*, is still unexplored. *P. clarkii* has been introduced worldwide for aquaculture purposes (HUNER, 1977). In Italy, it is presently diffused in many habitats and represents a threat for species composition, diversity, and biomass of freshwater communities (GHERARDI *et al.*, 1999). The aim of this study was therefore to investigate the impact of *P. clarkii* in different densities on mosquitofish fry, snails, and three aquatic macrophytes in a lake of Tuscany.

MATERIALS AND METHODS

Experimental design

A field experiment was carried out in a shallow oligotrophic lake in Tuscany (Lago della Doccia, Province of Pistoia) during August 2003. Twelve cages (bottom area: 0.45 m^2) were placed along a 30-m reach exposed to full sunlight from dawn to noon in a randomized block design (3 treatments x 4 blocks). Equal densities (having a similar total fresh biomass) of mosquitofish fry (*Gambusia affinis*), snails (*Physa* sp.), and three aquatic macrophytes (*Nymphoides peltata*, *Potamogeton* sp., and *Utricularia australis*) were introduced into the cages and were let recovering for one week before the experiment started. Adult male crayfish were then added to the cages in densities (crayfish x m^{-2}) of: 0 (Ctrl), 5 (Low), and 10 (High). The experiments lasted three weeks.

Impact Estimate

For both animals and plants, we assessed the final impact by measuring their fresh biomass at the end of the experiment (final biomass x m^{-2}). For *N. peltata* and *Potamogeton* sp., we evaluated the time-related impact by measuring, immediately prior to crayfish introduction and bi-weekly thereafter, shoot development of *N. peltata* (number of leaves x m^{-2}), and the density of *Potamogeton* sp. (number of plants x m^{-2}).

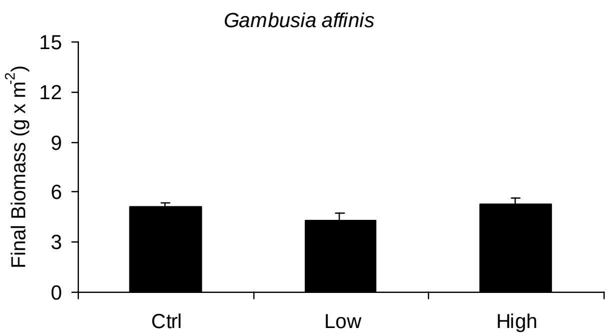

Fig. 1. Final biomass (mean + SE) of *Gambusia affinis* fry after three weeks of treatment with Ctrl, Low, and High. Ctrl, Low, and High indicate a density (number x m^{-2}) of: 0 (Ctrl), 5 (Low), and 10 (High), respectively, of *Procambarus clarkii*.

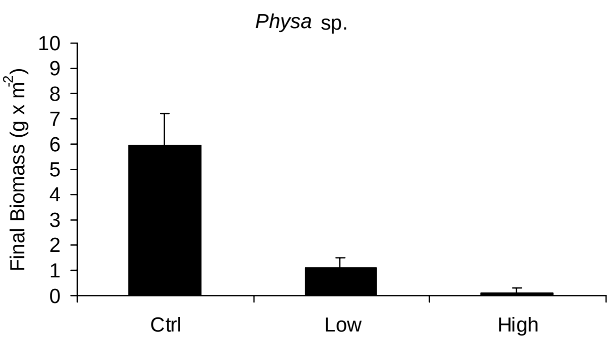

Fig. 2. Final biomass (mean + SE) of *Physa* sp. after three weeks of treatment with Ctrl, Low, and High. See Fig. 1 for the meaning of Ctrl, Low, and High.

Statistical Analyses

A randomized block designed ANOVA (density x block) was used to assess the impact on final biomass. A repeated measures ANOVA (density x day) was used to estimate the time-related impact on *N. peltata* and *Potamogeton* sp. In this case, we reported only F values that gave significant differences.

RESULTS

Gambusia affinis

The survival of mosquitofish fry was not affected by *P. clarkii* (Fig. 1); in fact, their final biomass did not differ among treatments ($F_{2,6}$ = 3.276, P>0.05).

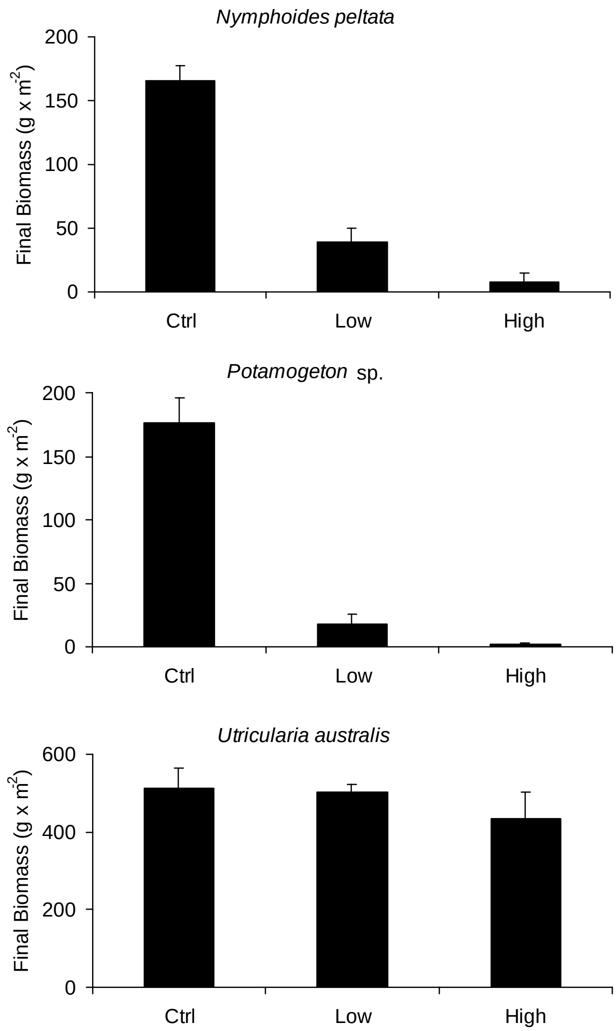

Fig. 3. Final biomass (mean + SE) of: *Nymphoides peltata Potamogeton* sp., and *Utricularia australis* after three weeks of treatment with Ctrl, Low, and High. See Fig. 1 for the meaning of Ctrl, Low, and High.

***Physa* sp.**

The final biomass of snails was negatively affected by low and high densities of crayfish ($F_{2,6}$ = 14.974, P<0.01) (Fig. 2).

Macrophytes

Low and high densities of *P. clarkii* significantly reduced the final biomass of *Nymphoides peltata* ($F_{2,6}$ = 39.227, P<0.01), *Potamogeton* sp. ($F_{2,6}$ = 58.204, P<0.01) but not of *Utricularia australis* ($F_{2,6}$ = 0.903, P>0.05) (Fig. 3). The impact on the number of *Nymphoides peltata* leaves (density: F=95.78, df=2&9, P<0.01; time: F=2.47, df=6&54, P<0.05; density x time: F=6.01, df=12&54, P<0.01) and of *Potamogeton* sp. plants (density: F=226.5, df=2&9, P<0.01; time: F=36.40, df=6&54, P<0.01; density x time: F=13.44, df=12&54, P<0.01) was different among the three treatments and changed with time (Fig. 4).

CONCLUSIONS

Our study clearly shows that:

1) low and high densities of crayfish exerted a negative impact on gastropods and on the two macrophytes *N. peltata* and *Potamogeton* sp. However, the impact on plants over time was stronger when higher densities of crayfish were present;
2) crayfish did not affect the survival of mosquitofish fry, probably because they are difficult to catch due to their mobility;
3) crayfish had no effect on *U. australis* although they could easily handle it; this plant may contain some chemicals that make it unpalatable to the crayfish (e.g., BOLSER et al., 1998).

These results indicate that also relatively low densities of *P. clarkii* can greatly affect the abundance of some species of submersed macrophytes and of invertebrates. Therefore, its introduction and its subsequent spread could represent a serious danger for the structure and the composition of the littoral zone of lentic aquatic habitats.

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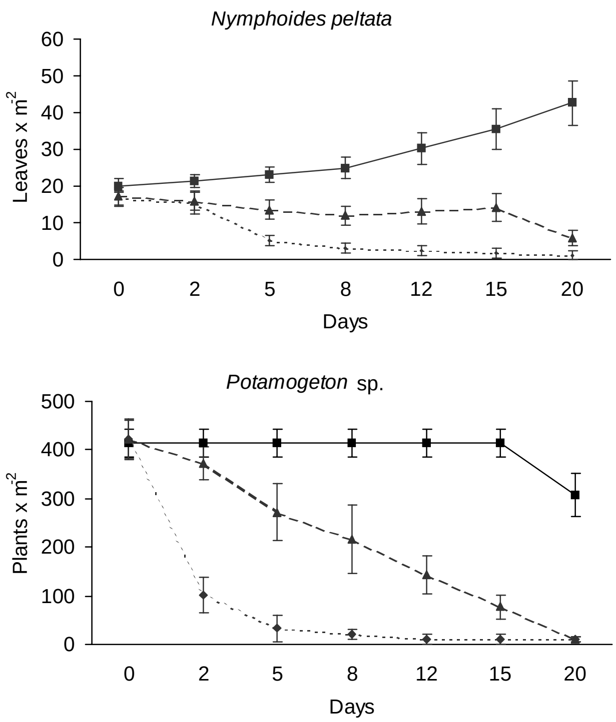

Fig. 4. Changes with time in the number per squared meter of *Nymphoides peltata* leaves and of *Potamogeton* sp. plants (means ± SE), compared among treatments. Ctrl: continuous line; Low: hatched line; High: dotted line. See Fig. 1 for the meaning of Ctrl, Low, and High.

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