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Short communication

Effect of gut passage in fish on the germination speed of aquatic and riparian plants

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ABSTRACT

How seed-eating animals influence the germination of endozoochorous plant species is of great relevance to our understanding of long-distance seed dispersal. To evaluate the effect of gut passage on the germination speed of aquatic and riparian plants, we fed seeds of 19 species to common carp (*Cyprinus carpio*) and Mozambique tilapia (*Oreochromis mossambicus*). Carp has a pharyngeal 'mill', compensating for lack of a stomach and teeth, while tilapia has tiny teeth and an acid stomach. *Potamogeton* species, *Alisma plantago-aquatica* and *Sagittaria sagittifolia* showed a continuous germination with relatively low, and constant germination rates throughout the germination period. In contrast, the seeds of *Myriophyllum spicatum* and *Nymphoides peltata* and those of the riparian species exhibited discontinuous germination, i.e. almost all seeds germinated within a few days. Compared to control seeds, we found on average a negative effect of gut passage on the germination speed for carp, but no effect for tilapia. However, several plant species deviated from this general pattern. For example, gut passage in carp enhanced germination speed of viable seeds relative to controls for *Potamogeton alpinus*, but reduced it for *Filipendula ulmaria*. Similarly, tilapia enhanced germination speed for *P. alpinus*, but reduced it for *P. pusillus*. We conclude that carp's efficient mastication affects the germination speed of plant species after gut passage, whereas stomach-passage in tilapia generally does not influence the germination speed when compared to control seeds. However, inherent variation across species in germination speed proved to be greater than effects of fish gut passage.

1. Introduction

How fruit- and seed-eating animals influence the germination patterns of endozoochorous plant species is of great relevance to our understanding of the ecology and evolution of animal-plant interactions (Traveset et al., 2007). For example, faster germination following gut passage, compared with uningested seeds, can have consequences for fitness (Figuerola and Green, 2004; Verdú and Traveset, 2005), as it may reduce competitive interactions via spatial and temporal separation, promoting seedling growth and plant fecundity (Seiwa, 1998; Dyer et al., 2000; Verdú and Traveset, 2005).

Effects of gut passage on seed germinations have been recorded extensively for birds and mammals (see reviews in Traveset and Verdú, 2002; Traveset et al., 2007). However, few investigations have focused on the effects of gut passage by fish on aspects of seed germination (see reviews in Correa et al., 2007, 2015) and the studies that have been performed tend to focus on germination success rather than the speed of germination. These studies have shown improved, unaltered as well as decreased seed germination after ingestion by fish (e.g. Agami and Waisel, 1988; Kubitzki and Ziburski, 1994; Pollux et al., 2006; van Leeuwen et al., 2015; Yule et al., 2015).

In a recent study (Boedeltje et al., 2015), we also found mixed responses in germination percentages among nineteen aquatic and riparian plant species after gut passage of two fish with contrasting modes of feeding and digestion: common carp (*Cyprinus carpio*) and Mozambique tilapia (*Oreochromis mossambicus*). Here we want to focus on patterns in the speed of seed germination following gut passage, rather than on germination percentages. This temporal aspect of germination has received far less attention, and has only been studied to date in a few plant species (Kubitzki and Ziburski, 1994; Pollux et al., 2006; van Leeuwen et al., 2015; Yule et al., 2015).

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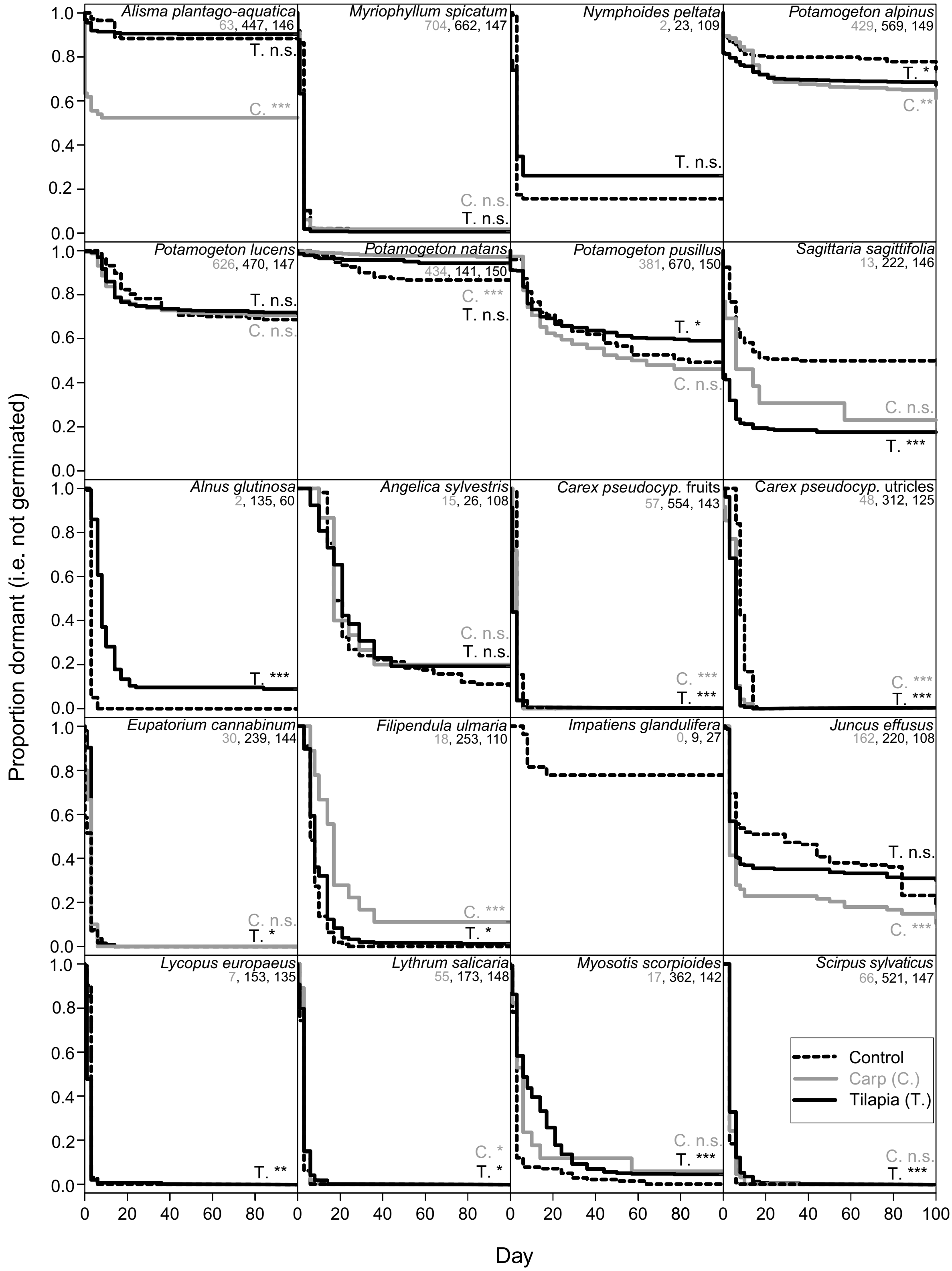

Fig. 1. Germination patterns of the aquatic species in the top two rows and riparian species in the bottom three rows. Top right numbers in each panel indicate the total number of viable seeds (germinated seeds + seeds that showed a positive tetrazolium test after the experiment) for carp (grey), tilapia and the control group, respectively. Patterns (lines) have been shown if the number of viable seeds was >10. Asterisks indicate significant differences compared to controls: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$. n.s. = not significantly different. Germination under the dark and cool (5 °C) conditions during storage was relatively high for *M. spicatum*, *P. alpinus*, *P. pusillus* and *S. sagittifolia*, where 10–20% germinated during storage, and generally low for riparian plants.

Grime et al. (1981) highlight that the speed at which seeds germinate can follow different distributions, distinguishing between species with a discontinuous germination, i.e. species where the majority of seeds germinate within a relatively short period, and species with a continuous germination, where cumulative seed germination increases gradually as only a small proportion of the