



Seasonal effects of waterfowl grazing on submerged macrophytes: The role of flowers



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ABSTRACT

Seasonal effects of waterfowl (*Fulica atra* and *Anas platyrhynchos*) grazing on submerged macrophytes (*Ruppia cirrhosa* and *Potamogeton pectinatus*) and the mediating role of flowers on plant consumption were evaluated by exclusion cages and tethering experiments deployed in a Mediterranean lagoon throughout the annual cycle. Despite the low waterfowl abundance recorded in summer, exclusion-cage experiments evidenced intense herbivory on the biomass, canopy height and flowers of *R. cirrhosa* (flowers abundance was ~8 times higher inside exclusion cages; $1015.7 \pm 269.8 \text{ flw m}^{-2}$). For *P. pectinatus*, exclusion cage experiments did not evidence waterfowl consumption, in spite of the presence of flowers, which suggest preference for reproductive tissues of *R. cirrhosa*. In addition, the higher abundance of *R. cirrhosa* flowers compared to *P. pectinatus* (~10 times higher inside the exclusion cages) was likely influenced by more intense herbivory on the former species. Although waterfowl abundance increased in autumn and winter, experiments did not evidence herbivory effects during that period, possibly because of enhanced availability of alternative resources and decreased plant biomass and canopy height reducing encounter rates. Hence, our results suggest that waterfowl effects on submerged macrophytes in Mediterranean aquatic ecosystems are strongly influenced by seasonal changes in the availability of food resources and its flowering events. The higher herbivory on *R. cirrhosa* and its flowers in summer suggest that waterfowl grazing may be driven by food preference for reproductive tissues, and could have a strong effect on the community structure and abundance of submerged macrophytes.

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1. Introduction

In aquatic ecosystems such as coastal lagoons and lakes, the submerged aquatic vegetation (SAV) plays a vital role: influencing nutrient dynamics and water chemistry; modulating the structure and dynamics of food webs; and increasing habitat diversity (see Jeppesen et al., 1998). These aquatic ecosystems are habitats for many herbivorous waterfowl that can also heavily use aquatic macrophyte resources during migratory stopovers and/or in locations hosting permanent populations (e.g. Michot and Nault, 1993; Baldwin and Lovvorn, 1994a,b). Several studies have reported long-term changes in aquatic vegetation coinciding with changes in the size of waterfowl abundances (Perrow et al., 1997; Søndergaard et al., 1998; Mitchell and Perrow, 1998; Blindow et al., 2000). High

densities of SAV can attract waterfowl (by providing food and shelter) that cause strong qualitative and quantitative effects on plant communities through effects on vegetation structure, species composition and by reducing stand biomass (Bortolus et al., 1998; Nolet et al., 2001).

Most of these studies conducted in temperate areas of North America, Europe and New Zealand, suggest that major impacts of waterfowl on the SAV occur during the autumn (Perrow et al., 1997; Mitchell and Perrow, 1998; Marklund et al., 2002) and winter (Kiorboe, 1980; van Donk, 1998), when macrophyte productivity is low and migratory events result in increased abundance of individuals (Søndergaard et al., 1996). Waterfowl herbivory is also important in temperate lakes during plant colonisation stages and at very low vegetation densities (Marklund et al., 2002; Körner and Dugdale, 2003; Hilt, 2006). In contrast, the few studies conducted in Mediterranean aquatic ecosystems suggest that, in general, waterfowl grazing does not have a strong effect on the biomass of submerged vegetation due to the high level of

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primary production (Mitchell and Perrow, 1998; Marklund et al., 2002; Sandsten et al., 2002). However, it has also been suggested that waterfowl in Mediterranean areas can have a strong qualitative effect on the structure of plant communities by selecting the most palatable species or their reproductive structures (Gayet et al., 2012; Rodríguez-Villafañe et al., 2007). A marked preference of herbivores for plants bearing abundant flowers and/or developing fruits has been suggested as eventually leading to a reduction in the number of seeds produced by these plants (Herrera et al., 2002) and could strongly impact the reproductive success of macrophytes.

Ruppia cirrhosa, *Potamogeton pectinatus* and *Zostera spp* have been reported as the dominant macrophyte species in Mediterranean lagoons, with a seasonal cycle characterised by declining biomasses in autumn and winter – particularly *R. cirrhosa* (Menéndez et al., 2002; Rodríguez-Pérez and Green, 2006) – and flowering event in summer (Menéndez and Comín, 1989; Prado et al., 2013). The waterfowl community in Mediterranean wetlands is dominated by the duck *Anas platyrhynchos* and the Eurasian coot *Fulica atra* whose abundances increase in autumn and winter, due to migratory concentrations (Mañosa et al., 2001; Hidding et al., 2009). *A. platyrhynchos* is considered to be mostly granivorous (Arzel et al., 2007) and coots (*F. atra*) mainly herbivorous, with both species having long been recognised to feed on submerged macrophytes such as *Potamogeton spp* and *Ruppia spp* as well as their seeds and flowers (Tubbs and Tubbs, 1983; Perrow et al., 1997; Figuerola et al., 2002, 2003; Green et al., 2002). However, ecological interactions between waterfowl and aquatic plant communities in Mediterranean lagoons need to be further investigated for the conservation of these natural habitats and the long-term sustainability of endangered and/or economically valued animal species, as well as the natural diversity of ecosystems.

In this context, the general objective of this study was to investigate whether seasonal differences in the two main populations of waterfowl (*A. platyrhynchos* and *F. atra*) and in the abundance of the two main submerged macrophytes (*R. cirrhosa* and *P. pectinatus*) can explain patterns of plant consumption within Mediterranean lagoons. In addition, we investigated the potential role of macrophytes' flowers in mediating waterfowl feeding preferences and overall impacts on macrophytes' biomass. With these aims, three specific objectives were assessed during three seasons: (1) waterfowl abundances of *A. platyrhynchos* and *F. atra*; (2) grazing impacts on both macrophyte species and their flowers (only in summer) by deploying exclusion cage experiments; and (3) plant consumption rates by tethering experiments.

2. Material and methods

2.1. Study site

The study was conducted at the Encanyissada coastal lagoon located within the Ebro Delta Natural Park (Spain, NW Mediterranean), a Natura 2000 wetland area of recognised international importance for waterbird conservation by the Ramsar Convention and by BirdLife International (Viada, 1998) where ca. 70% of the total surface is devoted to rice cultivation. The submerged vegetation in the lagoons is dominated by *R. cirrhosa* in high salinity areas (12–27‰) and by *P. pectinatus* in low salinity areas (3–12‰). Seasonal variation in macrophytes' biomasses within the lagoon have been reported values from $151.3 \pm 16.6 \text{ g DW m}^{-2}$ in August to $21.6 \pm 2.7 \text{ g DW m}^{-2}$ in February for *R. cirrhosa* and values from $162.6 \pm 24.4 \text{ g DW m}^{-2}$ in August to $54.8 \pm 13 \text{ g DW m}^{-2}$ in February for *P. pectinatus*. Flowering of *R. cirrhosa* has been reported in August in the lagoon, although flowers can start in June (personal observation). For *P. pectinatus*, flowering occurs in June to July (personal observation) ending by August, when only fruits (achenes) were

observed (Prado et al., 2013). In summer, water conditions (mainly increased water temperature and nutrient supply from rice agriculture) also contribute to the proliferation of fast-growing species such as floating macroalgae or epiphytic loads (Valiela et al., 1997; Menéndez, 2005). Waterfowl abundances in this area are especially notorious during autumn and winter, due to the migratory events and the abundance of wintering grounds, when ducks and coots become the most important species (Martínez-Vilalta, 1989, 1994, 1996). In this study, we focused on the herbivory of *A. platyrhynchos* and *F. atra* as both have been reported to feed on macrophytes as well as their seeds and flowers (Tubbs and Tubbs, 1983; Perrow et al., 1997; Figuerola et al., 2002).

2.2. Waterfowl abundance and behavioural observations

Monitoring the waterfowl community was conducted on a previously delimited area of the lagoon which included the two experimental areas of plots deployment. Waterfowl abundance was counted (using binoculars) from a fixed point located approximately 100 m from each area. At each study season (summer, autumn and winter) and during the 30-day experimental period, waterfowl were counted at the same time of the day on 4 random days. The number of individuals of *F. atra* and *A. platyrhynchos* in each study area was added to estimate total waterfowl abundance.

Feeding on the submerged vegetation and the possible disturbance of the experimental area by other bird species was also monitored by deploying a game camera (Day 6 Plotwatcher) facing the tethering and exclusion cages experiments at different days throughout the study period.

2.3. Exclusion cages experiment

To evaluate the grazing effect by waterfowl on macrophytes' biomass, six bird exclusion and six open cages were deployed randomly in two shallow areas of the lagoon (80–100 cm depth; separated ~1.5 km); one monospecific area with *R. cirrhosa* and another with *P. pectinatus*. Each plot (exclusion and control) covered an area of 1.5 m² and contained plant biomass (either *Ruppia* or *Potamogeton*) that was representative of the lagoon (Prado et al., 2013). Exclusion plots consisted of a rigid, plastic net above the canopy top (1 cm² mesh size) tied to four poles (1.5 m long, 10 mm diameter) inserted into the sediment, preventing the entrance of birds and enabling water circulation on the sides during occasional storms (total experimental area covered: ~300 m², see Fig. 1).

Cage experiments were deployed for a 30-day period in three different seasons: summer 2010 (from mid-June to mid-July: when flowering started and waterfowl abundances are the lowest); autumn 2010 (from mid-September to mid-October: when flowers are no longer available and waterfowl abundance increases); and winter 2011 (from mid-February to mid-March: when macrophytes abundance is the lowest and waterfowl abundance is the highest). After this period, 3 corers of 16 cm (Ø) were collected from central areas (defined by a minimum security margin of 0.3 m from each side) of each plot. To assess a possible shading effect by the cage mesh net, 3 additional corers were collected from the edges of the exclusion cages for further comparison (within the 0.3 m margin area). In each season, exclusion cages were removed after the 30-day experiment period to avoid the destruction of the plots or overlapping by repeated sampling. In autumn, green macroalgal blooms occurred in the experimental area and, as they were attached to macrophytes, their biomass was also quantified. At each sampling event, plants were placed into bags and carefully washed in the laboratory to remove attached sediments. We measured the canopy height, counted the number of flowers (in summer) and separated the attached macroalgae (in autumn). All samples were dried at 60 °C to constant weight and weighted to the nearest

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