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Short communication

# A manipulative experiment demonstrates that blooms of the macroalga *Ulvaria obscura* can reduce eelgrass shoot density

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## Abstract

This study reports on a manipulative experiment demonstrating that natural blooms of *Ulvaria obscura* (Kützinger) Gayral, a relatively understudied and easily misidentified green alga, can cause the loss of eelgrass shoots in a subtidal meadow. A total of 20 1 m<sup>2</sup> quadrats were set at the inshore edge of an eelgrass (*Zostera marina* L.) meadow near Blakely Island, Washington State, USA. Ulvoid algae were removed from experimental quadrats and left in control quadrats. Experimental quadrats lost 12% of their eelgrass shoots over 5 weeks, while control quadrats lost 54% of their eelgrass shoots. Thus, we conclude that natural blooms of *U. obscura* at the study site reduce eelgrass shoot density. © 2001 Elsevier Science B.V. All rights reserved.

*Keywords:* Green tides; *Zostera*; Seagrass; Drift algae; Algal blooms

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## 1. Introduction

Blooms of ulvoid macroalgae are reported to impact marine ecosystems in a variety of ways including the eradication of seagrass meadows and macroalgal communities (e.g. Sfriso et al., 1992, den Hartog, 1994, Anderson et al., 1996, Valiela et al., 1997). Most reports of this phenomenon are descriptive in nature: manipulative experiments demonstrating the loss of seagrasses because of high macroalgal biomass are rare (e.g. Holmquist, 1997,

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Maciá, 2000). This study reports field manipulations examining the effects of blooms of *Ulvaria obscura* (Kützinger) Gayral on eelgrass (*Zostera marina* L.).

*U. obscura* (Ulveae, Chlorophyta) is a circumboreal, primarily subtidal alga (Scagel et al., 1986). In northern Washington State, USA, masses of the alga are found at the edges of eelgrass (*Z. marina* L.) meadows or in dense, eelgrass-free patches in the middle of meadows (Nelson, unpublished data; Hayden, personal communication). This species cannot be distinguished from *Ulva* or *Monostroma* spp. in the field. It is monostromatic but unlike *Monostroma* the gametophyte and sporophyte are isomorphic. It can be distinguished from *Monostroma* in practice when dried: *Ulvaria* dries to olive drab or black while *Monostroma* dries to green (Gabrielson et al., 2000). Little is known about this genus: far more research has been conducted on the role of *Ulva* and *Enteromorpha* in green macroalgal blooms.

This study addresses two questions as follows.

1. Is there a negative correlation between the biomass of *Ulvaria* and eelgrass shoot density where both species co-occur?
2. Are naturally occurring *Ulvaria* blooms of sufficient magnitude to restrict growth of eelgrass?

## 2. Methods and materials

Experiments were performed in Armitage Bay, Blakely Island, Washington State, USA (48°32'14"N, 122°48'00"W). A large eelgrass meadow extends from -1.0 to -2.5 m MLLW through much of this bay. The inshore and offshore edges of the meadow are marked by substantial blooms of *U. obscura* during the summer. *Ulva fenestrata* (Postels et Ruprecht) and *Enteromorpha linza* (L.) (J. Agardh) are abundant in the intertidal but are not typically found associated with eelgrass at this site.

Changes in eelgrass shoot density were determined for three treatments: a midbed control, an edge control, and a removal treatment. The midbed control consisted of 10 replicate plots naturally lacking significant ulvoid algal biomass (mean  $\pm$  S.D. =  $0.05 \pm 0.06$  g dw m<sup>-2</sup>). The edge control and removal treatments consisted of a line of 20 replicate plots along the inshore edge of the eelgrass meadow where ulvoid biomass was high (mean  $\pm$  S.D. =  $143.99 \pm 74.95$  g dw m<sup>-2</sup>). Ten of these 20 plots were randomly assigned to the edge control and the remaining 10 plots were assigned to the removal treatment.

Replicate plots were 1 m<sup>2</sup> squares marked by steel concrete reinforcing bars (re-bar) imbedded in the sediments at the corners of the plot. Plastic mesh about 0.3 m high was placed around all plots (both controls and removal) and tied to the portion of the re-bar above the sediment surface. This mesh barrier was designed to minimize drift of ulvoids into the plots.

The experiment began on 12 July 1999 when all ulvoid algae were taken from the removal treatments, returned to the laboratory, identified, dried and weighed. Ulvoid algae in the removal treatment plots were collected, dried and weighed again on 26 July and 10 August. Algae were left in place in edge control and midbed control plots. Eelgrass shoots were counted initially on 12 July and at the end of the experiment on 17 August 2000 in all plots.

Changes in eelgrass density were expressed as a proportional change in shoot density. High variation in initial shoot density prevented the use of absolute change in shoot density in data analysis. Data were analyzed using a one-way analysis of variance. Multiple comparisons of means were made using the Bonferroni procedure. Preliminary data analysis indicated that the assumptions of normality and homoscedasticity were not violated thus allowing the use of these parametric tests (Neter et al., 1985).

Initial eelgrass shoot density was regressed on ulvoid biomass for data collected from the 10 removal treatment plots and 5 additional, randomly selected, plots in the middle of the meadow ( $n = 15$ ). Ulvoid biomass was not measurable from midbed or edge controls since destructive sampling would prevent their use as controls. The five additional midbed samples provided a greater range (i.e. low ulvoid biomass) than was available from the edge control plots alone.

### 3. Results

Eelgrass density was initially highest in the midbed control plots (mean  $\pm$  S.D. =  $51 \pm 19$  shoots  $m^{-2}$ ) and lowest at the edge control plots ( $24 \pm 13$  shoots  $m^{-2}$ ). Shoot density was negatively correlated with total ulvoid algal biomass (Fig. 1,  $m = -0.146$  shoots  $g\ dw^{-1}\ m^2$ ,  $R^2 = 62.7\%$ ).

Large quantities of ulvoid algae were taken out of the removal treatment plots on all three cleaning dates. Initially (12 July), an average of  $143.99 \pm 74.95\ g\ dw\ m^{-2}$  (mean  $\pm$  S.D.) of ulvoid algae was cleared from removal treatment plots. On the 26 July and 10 August cleaning dates  $40.18 \pm 27.52$  and  $114.55 \pm 43.18\ g\ dw\ m^{-2}$  of ulvoid algae were removed

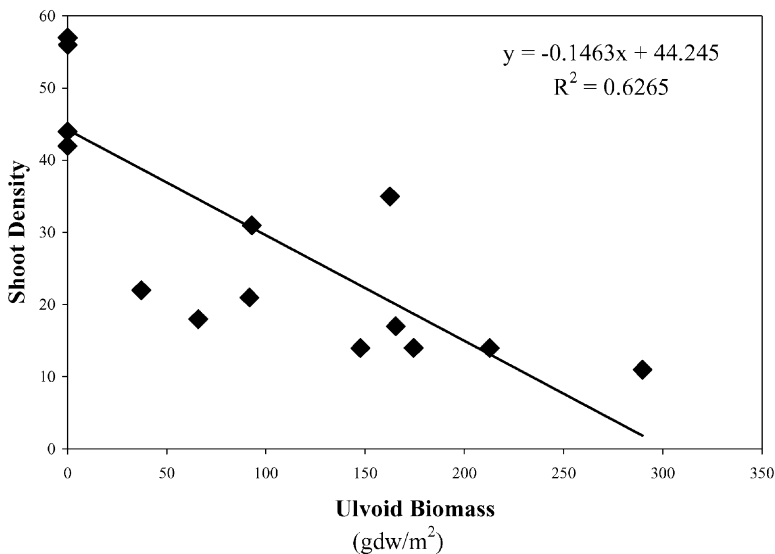


Fig. 1. Eelgrass shoot density vs. ulvoid algal biomass.

Table 1  
Impact of ulvoid removal on eelgrass shoot density

Treatment	Number of shoots <sup>a</sup>		Proportion change <sup>b</sup>
	Initial	Final	
Midbed control <sup>b</sup>	51 ± 19	59 ± 23	+17.2 ± 17.8%
Edge control <sup>c</sup>	24 ± 14	12.5 ± 8	-54.1 ± 21.6%
Ulvoid removal <sup>c</sup>	23 ± 12	19 ± 9	-12.4 ± 17.9%

<sup>a</sup> Little *Ulvaria* is present naturally in the midbed control plots.

<sup>b</sup> Large mats of *Ulvaria* were present initially. Control and ulvoid removal plots were at the inshore edge of the meadow.

<sup>c</sup> Values are mean ± S.D.

from these plots, respectively. Despite the presence of exclusion barriers ulvoid mats floated into the plots.

Eelgrass density declined slightly in ulvoid removal treatment plots and substantially in edge control plots; 12 and 54%, respectively (Table 1). Density increased in midbed controls (17%). The null hypothesis that midbed control, edge control, and removal treatments had equivalent effects on shoot density is rejected ( $F = 35.00$ , d.f. = 2 and 29,  $P < 0.005$ ). Bonferroni-corrected multiple comparisons show that all three treatment means are significantly different ( $P < 0.01$  for the least difference).

#### 4. Discussion

Naturally occurring blooms (i.e., in areas lacking significant anthropogenic eutrophication) of *U. obscura* in northern Washington are of sufficient mass to reduce eelgrass shoot density. These blooms cause the negative correlation observed between eelgrass shoot density and ulvoid biomass on the inshore edge of the meadow at the study site. Large mats of *Ulvaria* probably cause a similar phenomenon when found in gaps within meadows. Although such midbed gaps were not found at the study site, they do occur frequently in nearby meadows.

*Ulvaria* and eelgrass could be competing for one or more resources. Coffaro and Bocci (1997) have shown that light is a key resource in competition between eelgrass and *Ulva rigida* in the Lagoon of Venice based on a model of light, nutrients, and water motion. Exploitative competition may occur for other resources as well (e.g. for  $\text{HCO}_3^-$  during the day, or  $\text{O}_2$  at night). Alternatively, interference competition may play a role as *Ulvaria* blooms at our study site physically contact and cover eelgrass shoots on the edge of the meadow.

*Ulvaria* appears unable to outcompete eelgrass except when found in gaps or at the edges of meadows. Lack of light reaching the substratum among dense eelgrass shoots may prevent macroalgal growth. The dense baffle of eelgrass leaves may also serve as a barrier to drifting mats of ulvoid algae.

The slight loss of eelgrass shoots from ulvoid removal treatments is probably a result of our inability to completely exclude ulvoid algae from these treatments. Our mesh cages

reduced the encroachment of ulvoid thalli into removal treatments, but could not completely exclude them. Differences in the physical environment between the edge controls and the midbed controls are probably not responsible for the loss of eelgrass shoots from the edge of the meadow. Eelgrass can be found in the intertidal (up to and sometimes above 0 m MLLW) at nearby sites, suggesting that it could grow higher on the shore than it is found at Armitage Bay. The substratum at the edge of the meadow under study consisted of rich organic mud and had a very gentle slope both within the eelgrass and several meters shoreward suggesting that neither sediment composition nor slope limit the inshore extent of the meadow.

Manipulative experiments demonstrating negative impacts of macroalgae on seagrasses are rare. Holmquist (1997) examined the impact of drift specimens of *Laurencia poiteaui* (J.V. Lamouroux) M. Howe on *Thalassia testudinum* (Banks ex König) and associated invertebrate communities by adding the macroalga to mesh-enclosed treatment plots. Additions of macroalgae in this case dramatically reduced seagrass density and biomass. Maciá (2000) examined the effects of urchin grazing and drift algae (primarily *Laurencia* and *Dicotyota* sp.) on *Thalassia*. She found that macroalgae alone did not reduce shoot density. In combination with moderate to high urchin density, however, drift algae did cause decreased seagrass shoot density.

*U. obscura* is rarely studied and may be overlooked as an important part of green macroalgal blooms. Blooms of this species are primarily subtidal and are often accompanied by intertidal blooms of *Ulva* or *Enteromorpha* spp. (Nelson, unpublished data). Identification of only the intertidal species may thus be misleading. The superficial resemblance of *Ulva*, *Ulvaria*, and *Monostroma* may further hinder cursory surveys.

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