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Short-term effect of human trampling on the upper infralittoral macroalgae of Ustica Island MPA (western Mediterranean, Italy)

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The short-term response of Mediterranean upper infralittoral macroalgal species to experimental human trampling was investigated. Disturbances of six different intensities were applied within the integral reserve of the Ustica Island marine protected area (Italy, Mediterranean Sea). The dominant macroalgal species *Cystoseira brachicarpa* v. *balearica* and *Dictyota mediterranea* were strongly affected by human trampling. Higher levels of disturbance significantly affected both algal percentage cover and canopy at an increasing rate. Three months after trampling, for both variables it was highlighted that the algal recovery from disturbance was incomplete, being significantly different among trampling intensities. The current study revealed that in the short-term it was not possible to identify critical levels of trampling that are sustainable for this shallow community.

INTRODUCTION

Many studies have emphasized the role of natural disturbance (e.g. both physical and biological) in modifying and affecting the composition and structure of rocky intertidal and upper infralittoral communities (Paine & Levin, 1981; Sousa, 1984; Dayton et al., 1992). Only quite recently, however, interest in anthropogenic disturbances (e.g. recreational human trampling) as direct impacts on these communities has been highlighted (Povey & Keough, 1991; Brosnan & Crumrine, 1994; Keough & Quinn, 1998; Schiel & Taylor, 1999). At a local spatial scale, human trampling may cause a physical removal of a species (or a group of species) thus affecting population dynamics and indirectly the diversity of the entire community (Brosnan & Crumrine, 1994). Several studies carried out world-wide on shallow rocky shores revealed that canopy-forming macroalgae may be strongly damaged by human trampling showing a rapid decrease both in algal canopy and cover (Povey & Keough, 1991; Brosnan & Crumrine, 1994; Schiel & Taylor, 1999; but see Milazzo et al., 2002 for review). By contrast, algal turfs were more resistant to disturbance showing an increase in coverage (Brosnan & Crumrine, 1994). This is of particular interest, since in sites where the intensity of usage by humans is particularly high the seascape of very shallow rocky areas may be dominated by algae with low levels of structural complexity (Brown & Taylor, 1999).

The effects of human trampling disturbance on Mediterranean rocky shallow areas have not been previously examined. Very recently increasing tourism at popular sites is giving rise to widespread concern that, when intensive, human trampling may contribute to an alteration of marine shallow communities at local scale (Milazzo & Ramos-Esplà, 2000; Milazzo et al., 2002).

The Ustica Island marine protected area (MPA) (western Mediterranean, 10°43′43″E–38°42′20″N) known for its diverse and rich subtidal communities has long been a tourist attraction. Because of easy accessibility and shelter from waves, along with some facilities provided, visitors tend to gather in two small sections of the integral reserve coast, where swimming is allowed by the management body. There is evidence that rocky shallow communities of heavily used sites like these, may be impacted by visitor trampling and these impacts may conflict with conservation goals (Eckrich & Holmquist, 2000). The major aims of the present study were to: (i) experimentally assess the immediate response of the upper infralittoral algal assemblage of the Ustica Island MPA to diverse short-duration human trampling intensities determining which kind of intensity of human recreational use may affect this shallow community; and (ii) assess the potential early recovery of macroalgal species.

MATERIALS AND METHODS

The study was carried out within the integral reserve of the MPA, on the exposed west-north-west rocky shore of Ustica Island. In late May 2000, the experimental transects were located on a horizontal basaltic platform along 300 m of shore.

To test the effects of various short-duration human trampling intensities on the macroalgal assemblage of Ustica Island, six different experimental intensities were considered: 0 (control), 10, 25, 50, 100, and 150 pedestrian passes. Eighteen transects (0.4 m wide and 2 m long) were initially located in the study site, while intensities were assigned randomly only on 12 transects trampled by an operator wearing gumboots (size 8). Two interspersed replicated transects of each intensity were considered (about 10 m apart).

The abundance of erect macroalgae were visually assessed respectively, before trampling, immediately after, and three months later, using a 30×30 cm quadrat. Five random and independent measurements of percentage

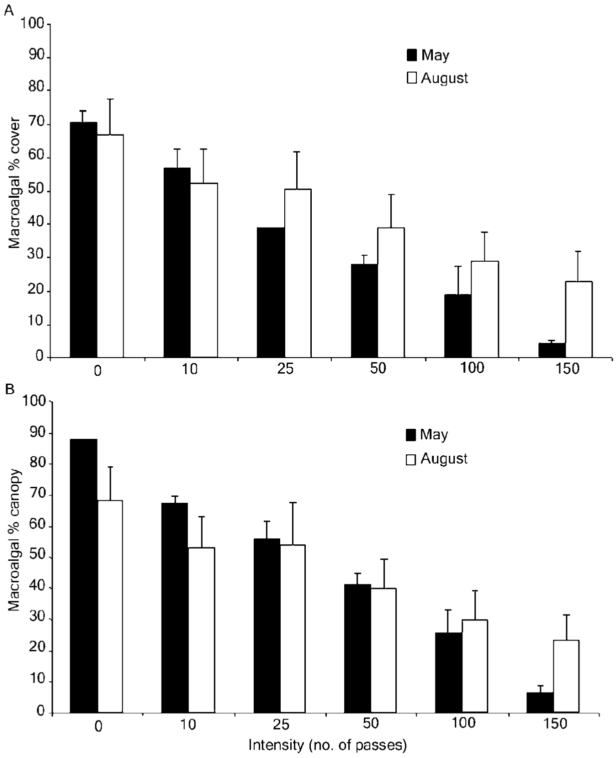

Figure 1. Average (±SD) percentage cover (A) and percentage canopy (B) of macroalgae damaged at different trampling intensities immediately after trampling and three months later.

cover (% Cr) and percentage canopy (% Cy) (*sensu* Brosnan & Crumrine, 1994) of the canopy-forming macroalgae *Cystoseira brachicarpa* J. Agardh v. *balearica* (Sauvageau) Giaccone and *Dictyota mediterranea* (Schiffner) G. Furnari were carried out in each transect. During trampling the macroalgae detached from the substratum were collected by three snorkellers and stored in a nylon bag (0.425-mm mesh size). In the laboratory, algal dry weight (DW) was assessed (Littler & Littler, 1985).

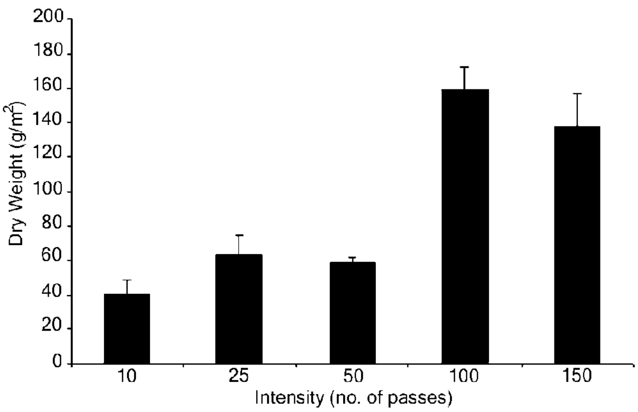

Figure 2. The mean macroalgal biomass (±SD) detached from the substratum at different trampling intensities.

Table 1. *Analysis of variance of percentage cover and percentage canopy of erect macroalgae immediately after experimental trampling at different intensities.*

		% Cover		% Canopy	
Source of variation	df	MS	*F*	MS	*F*
Intensity: In	5	50.4	48.61***	8600.8	94.81***
Transect: Tr(In)	6	1.0	3.02*	90.7	1.21 n.s.
Residuals	48	0.3		75.2	
Transformation		sqrt(X+1)		none	
Cochran's test		C=0.26, *P*>0.05		C=0.19, *P*>0.05	
SNK test Intensity		0=10>25=50=100>150		0>10>25>50>100>150	

n.s., not significant; *, $P<0.05$; ***, $P<0.001$.

Table 2. *Analysis of variance of percentage cover and percentage canopy of erect macroalgae three months after trampling at different intensities.*

		% Cover		% Canopy	
Source of variation	df	MS	*F*	MS	*F*
Intensity: In	5	2666.0	37.64***	2818.7	42.82***
Transect: Tr(In)	6	70.83	0.69 n.s.	65.83	0.57 n.s.
Residuals	48	102.29		115.83	
Transformation		none		none	
Cochran's test		C=0.13, *P*>0.05		C=0.18, *P*>0.05	
SNK test Intensity		0>10=25>50>100=150		0>10=25>50>100=150	

n.s., not significant; ***, $P<0.001$.

The early algal recovery from different trampling intensities was quantified in late August 2000 to determine whether there were no differences among intensities in the short-term.

Analysis of variance (ANOVA) was used to test for the immediate effect of trampling and the potential early recovery, with intensity (In) as fixed, orthogonal factor (6 levels), and transect (Tr) nested in intensity as random factor (2 levels). Cochran's test was used to check for the homogeneity of variances (Winer, 1971). Whenever necessary data were transformed. Student–Newman–Keuls (SNK) test was employed to separate means (at α=0.05) following significant effects in the ANOVAs (Underwood, 1997). Differences of algal biomass dislodged during trampling were compared at different intensities using one-way ANOVA. The GMAV 5.0 software (University of Sidney) was used to perform statistics.

Destructive sampling was carried out to investigate the algal assemblage of the study area from 0.3 to 0.5 m below mean low water. Three replicated samples of 400 cm^2 were collected respectively in late spring and late summer by scraping algae off the substratum with hammer and chisel. In the laboratory, algal samples were identified to species level (Coppejans, 1983) and per cent algal cover was also calculated (Littler & Littler, 1985).

RESULTS AND DISCUSSION

The seascape of the study area was homogeneously carpeted by a well-developed community of photophilic algae forming a multi-layered and spatially complex disposition of algal species, typical of non-polluted Mediterranean rocky shallow areas (Ros et al., 1984). A total of 47 algal species were collected in both samplings and these were numerically dominated by Rhodophyta (63.8% of the total number of species) while Phaeophyta (21.3% of all species), and Chlorophyta (12.8% of all species) were less frequent. On average the total number of algal species collected in late summer was higher than late spring samples (respectively 29.7 ±1.5 SD and 24 ±1.7 SD). The analysis of the % Cr data calculated on the whole algal assemblage species revealed that the canopy-forming brown algae *Cystoseira brachicarpa* v. *balearica* and *Dictyota mediterranea* were the dominant species in both late spring and late summer samples. However, a clear increment in *Laurencia obtusa* (Hudson) Lamouroux % Cr was evident from late May to late August, increasing on average from 1.3% (±0.6 SD) to 25.3% (±5 SD).

Before trampling the experimental transects showed no significant differences both in macroalgal percentage cover and percentage canopy cover (% Cr, $F_{6,48}$=1.62, $P>0.05$; % Cy, $F_{6,48}$=1.08, $P>0.05$). This was necessary to demonstrate that potential initial differences in the macroalgal % Cr and % Cy did not affect the damage caused by experimental trampling. On average macroalgae covered about 70.5% (±7.5 SD) of the substratum, ranging from 55 to 80%. Similar results were observed on % Cy values (on average 86.6% ±5.4 SD). In some cases a homogeneous canopy near to 100% was recorded.

Immediately after trampling, erect macroalgae revealed a great susceptibility to human physical disturbance (Figure 1A,B). Both variables showed highly significant differences (% Cr, $F_{5,48}$=48.61, $P<0.001$; % Cy, $F_{5,48}$=94.81, $P<0.001$) among levels of intensity (Table 1). Moreover, the effects of trampling were slightly dissimilar in space, revealing significant differences in algal % Cr among transects ($F_{6,48}$=3.02, $P<0.05$) (see Table 1). The SNK tests showed different results at increasing levels of human trampling intensity (Table 1). No significant differences in % Cr were observed between low levels of intensity (10 pedestrian passes) and control transects. Intermediate human trampling intensities (25, 50 and 100 pedestrian passes) had similar effects on algal cover, but significantly affected macroalgae when compared with 0 and 10 passes. It is noteworthy that after 150 tramples % Cr was significantly lower (4.2% ±0.8 SD) than other levels of intensity, showing a decrease of more than 65% with respect to controls (Figure 1A).

A different pattern may be highlighted analysing the macroalgal canopy cover. Higher levels of human trampling significantly affected % Cy at an increasing rate (see SNK test, Table 1). Considerable variations in % Cy occurred among transects at different intensities, ranging from 88% ±7.5 SD (controls, no passes) to 6.5% ±2.4 SD (highly impacted transects, 150 passes) (Figure 1B).

Individual macroalgal plants (mainly *Cystoseira brachicarpa* v. *balearica* and *Dictyota mediterranea*) were damaged in different ways by human trampling. At low–intermediate trampling intensities (i.e. 10, 25, and 50 passes) the thin macroalga *D. mediterranea* was strongly damaged, while the fleshy macroalga *C. brachicarpa* v. *balearica* was only initially injured by the increasing loss of fronds. Under severe damage (100 and 150 passages) *D. mediterranea* plants were completely uprooted and *C. brachicarpa* v. *balearica* individuals were reduced to holdfasts. As reported in other non-Mediterranean studies, the vulnerability to human trampling may depend on the nature and morphology of algal plants (see Keough & Quinn, 1998). In general, branching and foliaceous macroalgae are more susceptible than encrusting and low profile forms (i.e. algal turf) (Brosnan & Crumrine, 1994). In the present study, this evidence was further confirmed by the analysis of macroalgal biomass that was greatly affected by human trampling showing highly significant differences ($F_{5,24}$=60.7, $P<0.001$) among intensities (Figure 2). Assuming that the algal biomass detached from the substratum in control transects was null, low–medium human trampling intensities (10, 25 and 50 passes) revealed values of algal biomass very similar from one another (about 50 g m^{-2}). By contrast, at 100 and 150 pedestrian passes the algal biomass detached by trampling was higher of three orders of magnitude (about 150 g m^{-2}).

In late August, both % Cr and % Cy highlighted that the algal recovery from experimental trampling was incomplete, being significantly different among trampling intensities (Figure 1A,B; Table 2). Identical trends between intensities were revealed for both variables by the analysis of the SNK tests (Table 2). Three months after trampling, there was a clear evidence of a nonlinear relationship between intensity of disturbance and algal cover and canopy: intense disturbances (i.e. 100 and 150 pedestrian passes) have still produced a very large change, the two low levels (i.e. 10 and 25 passes) produced similar patterns of algal cover, while 50 pedestrian passes resulted in canopy-forming macroalgae cover and canopy being intermediate between undisturbed and heavily disturbed

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experimental transects (see SNK tests, Table 2). Changes in the short-term relationships revealed by post-hoc comparison tests (SNK) are very likely related to an increment over time in the cover of turf forms such as the rhodophycean *Laurencia obtusa*, and to an increased capability to recover of macroalgae from holdfasts in highly impacted transects (Figure 1A,B).

Erect macroalgae occurring at shallow waters in the Ustica Island MPA revealed a high susceptibility to human physical disturbance and this may shift the entire community to an alternate state dominated by low profile algae. Although this was not directly highlighted in this study, other researches carried out in the Mediterranean Sea showed that *Cystoseira* displacement may induce a rearrangement of the algal assemblage, increasing the relative abundance of some pre-existing organisms (i.e. turf forms) and decreasing that of others (i.e. epiphytes) (Benedetti-Cecchi & Cinelli, 1992).

In conclusion the current study revealed that, in the short-term, it was not possible to identify critical levels (i.e. thresholds values) of trampling that are sustainable for this shallow community. Some evidence, however leads us to assert that, although this may have implications for marine conservation and correct management practices in some Mediterranean MPAs, we should also take into consideration that upper infralittoral macroalgal species may have high resilience (Ballesteros, 1991), being able to recover if the intervals between pulse disturbances is long enough (Keough & Quinn, 1998). On the contrary, established mats of algal turfs, as a result of intense human trampling (Brosnan & Crumrine, 1994), may drastically inhibit the recruitment of canopy forming algal species (i.e. *Cystoseira* spp.) (Benedetti-Cecchi & Cinelli, 1996), decreasing the structural complexity of the entire community (Brown & Taylor, 1999). However this is not the case of many Mediterranean rocky shallow areas (like the Ustica Island MPA), where the human physical disturbance occurs in the short-term, being concentrated in late spring and summer (Milazzo & Ramos-Esplà, 2000).

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