CAUSES OF INFRALITTORAL BARRENS IN THE TURKISH MEDITERRANEAN AND POTENTIAL FOR ECOSYSTEM RESTORATION

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Abstract
The goal of the study was to understand rapid change of benthic communities in the Turkish Mediterranean infralittoral, from dense algal forests to barrens. We conducted caging experiments in three sites and observed that macroalgae grew rapidly inside the cages but not outside. Juvenile rabbitfish invaded the cages at the end of the experiment and removed all algae within. These results suggest that the large abundance of Lessepsian herbivorous fishes may be a major cause for the desertification of the Turkish Mediterranean infralittoral. The restoration of the ecosystem may require the removal of Lessepsian fish species.
Keywords: Algae, Biodiversity, Eastern Mediterranean, Monitoring, Lessepsian migration

Introduction
The Turkish Mediterranean infralittoral was dominated by abundant algal forests, dominated by the genus *Cystoseira* and Dictyotales, only a decade ago (pers. obs.). Current observations along the Turkish coast revealed that macroalgae have disappeared from many locales, and been replaced by extensive barrens with virtually no macroalgae. Sea urchins, which are the main cause of barrens elsewhere in the Mediterranean [1], were also absent in these barrens; but the alien herbivore from the Red Sea, the rabbitfish (*Siganus luridus* and *S. rivulatus*), was very abundant. In contrast, on Greek islands of the Dodecanese, where environmental conditions are very similar but rabbitfish were much less abundant, *Cystoseira* forests dominated infralittoral communinities. We thus hypothesized that the desertification of the Turkish Mediterranean infralittoral is due to the grazing activity of the abundant Lessepsian rabbitfish. To test this hypothesis, we conducted visual censuses of fish and benthos, and a caging experiment, in several locales of the Turkish coast.

Materials and Methods
To determine the extent of barrens and the structure of the herbivore community, we conducted underwater visual belt transects using scuba at a depth of 10m in five sites of the Turkish Mediterranean. We counted, identified, and estimated the size of all fishes within 15 replicate 25x5m transects per site, and calculated the biomass of algae by scrapping 20 25x25cm quadrats per site. We counted sea urchins using 150 50x50cm quadrats per site. In three sites with extensive barrens (Kas, Fethiye, and Bodrum) we conducted caging experiments to test wheter the absence of algae was due to the grazing by fish. We installed 12 60x40x25cm cages with plastic mesh on each site. Once a month, cages were lifted, and cages and nearby control quadrats were photographed. Algal cover of each taxa was estimated using Photogrid. A subsample of algae were collected to calculate the relationship between cover and biomass. In addition, pH, salinity, oxygen and turbidity were measured, and fish surveys were conducted around the cages.

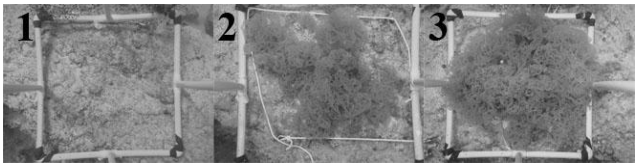

Fig. 1. Monitoring the algal growth within a cage at Kas during three months in 2009: 1) April, 2) May, 3) June

Results and Discussion
Macroalgae grew very rapidly inside the cages (Fig. 1) - in some cases from 0 to 200 g m^{-2} in four months - but not outside the cages (Table 1). Sea urchins were very rare in the study areas, and were not observed grazing around the cages. The native herbivorous fish *Sarpa salpa* was rare, but rabbitfish were very abundant throughout the study period. In September and October, rabbitfish recruitment was very high, and rabbitfish juveniles entered the cages and consumed every alga within.

Tab. 1. Algal biomass inside and outside the cages during the experimental period (g m^{-2})

Workspace		April	May	June	July	August	September	October	November
Kas	inside	59.5	95.3	95.0	200.3	68.0	0.0	0.0	9.3
	outside	0.0	0.2	0.0	69.1	42.2	0.0	0.0	0.0
Fethiye	inside	0.4	6.2	16.2	33.0	13.5	0.0	0.0	0.0
	outside	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0
Bodrum	inside	6.6	20.2	41.7	17.8	29.3	38.4	35.3	3.8
	outside	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0

In contrast, *Cystoseira* spp and Dictyotales were observed in the mediolittoral, near the surge zone, where fish grazing activity is more limited.
These results suggest that herbivorous fishes, not sea urchins or environmental factors, are responsible for the creation of infralittoral barrens in the Turkish Mediterranean coast. This is the first documented case in the Mediterranean sea where herbivorous fishes create barrens, and where Lessepsian fishes have dramatically transformed the ecosystem, from one dominated by lush and diverse brown algal forests to another dominated by bare rock.
Restoration of algal assemblages ocurred at first successional stages and within small enclosures. The question is whether restoration efforts could be conducted at large scales. Based on our results, such restoration efforts may have to be based on overfishing of the introduced rabbitfishes *Siganus* spp.

References
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