CONCLUSION

The location of Caulerpa prolifera on the Island of Lokrum is unique for the Adriatic and probably also for the Mediterranean Sea. The location is unique because the alga is developed on the vertical rocky bottom exposed to the strong hydrodynamics. C. prolifera groves as epiphyte on the algae which formed vegetation typical for the sciaphilic, vertical rocky bottom with reduced light intensity.

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THE «CLADOPHORA» PHENOMENON IN THE COASTAL WATERS OF CYPRUS

ABSTRACT

The seasonal and spatial variability of rocky intertidal phytobenthic communities, with a particular emphasis on the green macroalga Cladophora spp., were examined in Liopetri Bay, Cyprus, along with changes in nutrient inputs from a fish-hatchery. Increased nutrient inputs, and particularly nitrates, in the effluents of the hatchery resulted in significant changes in the composition and density of intertidal rocky phyto-communities and particularly, in the stimulation of the overgrowth of the macroalgae Ulva spp. and Cladophora spp. in the adjacent area of the hatchery. Cladophora spp. then expanded in the Bay most likely by wind-driven currents and waves, while it continued its proliferation presumably by other nutrient sources such as the discharge of the nitrates-rich groundwater horizon, domestic effluents and the open sea fish cages. Based on the data on the situation of Cladophora spp. along the broader coastline of Cyprus, it seemed that Cladophora spp. appears every year in «normal» growth around most of the coasts of Cyprus; in the presence of excess nutrient inputs combined with high temperatures it causes eutrophication events.

KEY-WORDS

Macroalgae, fish-hatchery, nutrients, Cladophora spp., Liopetri Bay (Cyprus)

INTRODUCTION

Over recent years, there have been considerable ecological changes in the coastal waters of Cyprus, including the pronounced proliferation of ephemeral macroalgae such as Ulva spp., Enteromorpha spp. and Cladophora spp. The Cladophora species found in Cyprus waters has been identified as C. patentiramea (?) (Boudouresque and Verlaque, pers. com., 1991), a Red Sea migrant and as C. vagabunda (L.) (van den Hoek, pers. com., 1999). Since taxonomic identification of this genus is very complex and difficult (Dodds and Gudder, 1992), for the purpose of this study it is reported as Cladophora spp.. The macroalgae, Ulva spp. and Enteromorpha spp., were observed to be growing in a constrained area in the immediate of a nutrient source (e.g., fish farms) (Hadjichristophorou, 1990), while growths of the filamentous alga Cladophora spp. created nuisance blooms during the period 1990-1991, that resulted in mass aggregates of free-floating filaments along the coastline of Cyprus and, particularly, in the embayments of Liopetri Bay and the touristic beaches of Ayia Napa (Hadjichristophorou 1990). The massive growth of Cladophora spp. was attributed to the increased nutrient inputs and, particularly, to the excess nitrates pulses from the seepage of the coastal groundwater horizon (Baird and Muir, 1990), combined with the complex interactions of other synergistic factors such as increases of water temperature, mild weather conditions, appropriate substrate etc. (Hadjichristophorou, 1990).

In the present paper, we attempt to determine the main triggering mechanisms governing the Cladophora spp. proliferation along the Cyprus coastline and, in particular, in the shallow

embayments of Liopetri Bay. For this purpose, we provide data on the ecological changes of rocky intertidal phyto-communities in relation to nutrient inputs from the Telia Fish-Hatchery, in the Liopetri Bay as well as data on the situation of Cladophora spp. along the broader coastline of Cyprus.

RESULTS & DISCUSSION

Seasonal variations in effluents discharge from the fish hatchery to the coastal waters of Liopetri Bay contributed significantly to the spatial and temporal distribution and composition of macroalgae. Increases of nutrient inputs and particularly nitrates (Fig. 1), in the Liopetri Bay, at the vicinity of the hatchery, enhanced primary production with the most prominent effect on fast-growing macroalgae. While the phytal system of the rocky intertidal zone of the Bay mainly consisted of the brown macroalga beds of Cystoseira combined with the Red macroalgae, Laurencia obtusa and L. papillosa, the phytal system at the outfall site of the hatchery is primarily dominated, throughout the year, by the ephemeral macroalga Ulva and the red alga Hypnea musciformis. The most significant change in macroalgae composition occurred in May 1998, in March and June 1999 during an algal bloom of the Cladophora spp (Fig. 3).. This macroalga was firstly observed in abundance as an epiphyte on Cystoseira at the coastal area between the fish hatchery and the Potamos, when the nutrient pulses from the hatchery were very high and the N/P ratio was significantly higher than the Redfield ratio (Fig.1, 2). In a short period of time, Cladophora spp. extended easterly to the Liopetri Bay reaching dense populations, while, mass aggregates of its floating fragments were drifted by wind-driven currents and accumulated at the adjacent touristic beaches of Ayia Napa creating nuisance problems. Based on our observations, Cladophora spp. presumably detached from its original substrate by the waves, drifted by the currents until it became attached to the new substrate and/or accumulated in loose mats, while it continued to be photosynthetically active since there were other nutrient sources such as domestic effluents. Similar observations of this passive mechanism of Cladophora were reported by Dodds and Gudder (1992). In addition to this, the reproduction and propagation mechanisms of this alga contributed significantly to its expansion and colonization on new areas.

The enhanced nutrient content of the hatchery's effluents, and of nitrates in particular, is to a large degree due to the fact that the water supply for the hatchery needs is obtained through pumping from the adjacent boreholes, which are connected to the local aquifer, which is overloaded with nutrients (Charalambides, Geol. Dept., pers. com.). An analysis of the water inflow from the boreholes of the hatchery in June 1998, showed a salinity range from 33.8 to 37.1 ‰ and significant high nitrate concentrations, from 600 to 3500 mg L-1 (data not shown). It is evident from the above that some quantities of fresh water are obtained from the aquifer, which has high nitrates content. However, the hatchery needs to avoid this practice in order to reduce significantly the nutrient content in its effluents by pumping directly nutrient-poor seawater. Furthermore, a pre-fattening (fry-production) procedure was being carried out in the hatchery, resulting in increase concentrations of nutrient inputs in its effluents.

Based on the N/P ratios in the Liopetri Bay, it appeared that macroalgae most of the time were limited by nitrogen except at the vicinity of the hatchery during May 1997, February and May 1998, March and June 1999, which were limited by phosphorus (Fig.2). The wide range of

N/P ratios (1.73 ± 0.06 to 131.7 ± 5.2) (Fig.2) was primarily due to marked changes in dissolved inorganic nitrogen (DIN) species (NO3--NO2-), although there were significant increases in phosphate concentrations in the vicinity of the hatchery throughout the year (Fig.1). However, when the N/P ratio observed to be greater than 50 (February and May 1998, March and June 1999), Cladophora spp. was found in densities in the area causing eutrophication problems. Moreover, N/P ratios in the coastal waters of Liopetri Bay (except in May 1997, February and May 1998, March and June 1999) were considerably lower than those found in the open East Mediterranean Sea which was shown to be phosphorus-limited system (Krom et al., 1991). These differences may indicate preferential uptake of nitrogen, primarily by the ephemeral macroalgae (i.e., Ulva and Cladophora). In fact, a recent study by Valiela et al. (1997) have shown that Cladophora can be extremely productive by absorbing and storing large amounts of nitrogen.

While nutrients are considered the primary factor for the Cladophora spp. blooming, the interactions with other environmental factors, such as temperature and light, are likely to be also important in the enhancement of their utilization (Dodds and Gudder, 1992). In fact, responses to temperature were used to describe the seasonal fluctuations of freshwater Cladophora (Muller, 1983), and thermal effluents have been shown to be related to increased biomass (Squires et al., 1979). There are also cases where high temperatures may cause summer die-offs in freshwater systems but this depends on the growth responses of a particular species to temperature (Dodds and Gudder, 1992). In the Liopetri bay, higher temperatures were observed between May and June for the years 1997 and 1998 and these were likely to accelerate the assimilation of nutrients by Cladophora spp. and its subsequent growth. However, in the case of Liopetri Bay, excess nutrient inputs combined with high temperatures may have stimulated the overgrowth of Cladophora spp. in the area. Although water temperature rose for all the coastal waters of Cyprus, no Cladophora spp. blooming was observed, except in Liopetri Bay, due to the absence of excess nutrient inputs.

While effluent inputs from the hatchery impacted a confined area at the vicinity of the farm, other nutrient sources may be significantly contributed with their inputs to the proliferative growth of Cladophora spp.. Significant components of the nutrient sources in the area are the discharge of the nutrient-rich groundwater horizon and fertilizers run-off from the extensive agricultural land found in the area. Fertilizers run-off for the past two years was not expected to be significant, since the last years' rainfall was at its minimum and flooding events did not occur. On the other hand, nutrient content of the boreholes along the coastline of Liopetri showed significant concentrations of nitrates (Charalambides, Geol. Dept., pers. com.), which in turn, may seep to the bay and subsequently, fuel the expansion of Cladophora spp.. In 1990, there was an apparent seepage of the N-rich groundwater to the Bay, which was largely related to the Cladophora spp. bloom (Baird and Muir, 1990). Although the groundwater seepage is considered one of the most important nutrient sources in the area, the degree of impact for the past two years remains uncertain and needs to be investigated, since, the groundwater level presumably is lower than in previous years due to the last two years prevailed dryness. Furthermore, the potential impact from the domestic effluents and the fish cages into the coastal waters of the Bay needs also to be investigated.

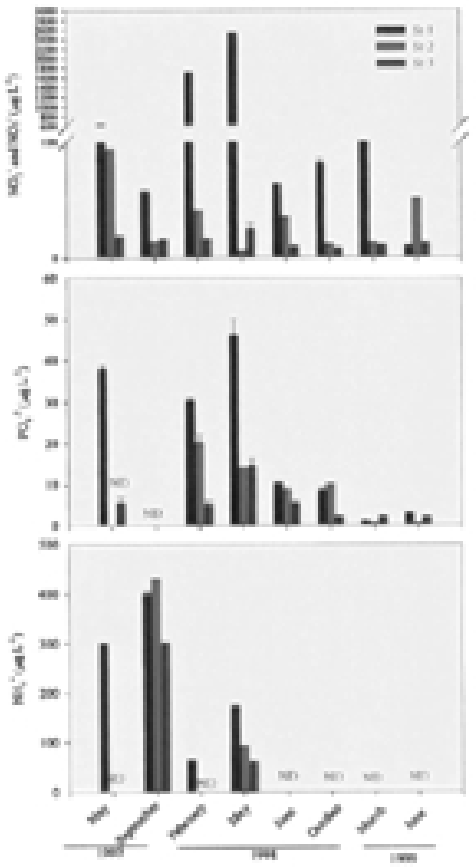

Figure 1. Nutrient (NO_3^--NO_2^-, PO_4^{3-}, NH_4^+) concentrations ($\mu g\,L^{-1}$) from the three stations in Liopetri Bay, sampled from May 1997 - June 1999. (ND = Not Detected)

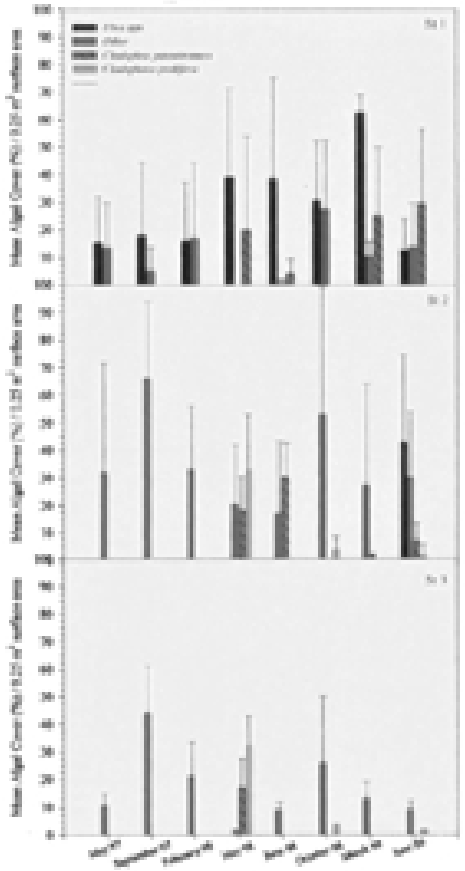

Figure 3. Percentage (%) mean algal cover per 0.25 m^2 surface area from the three stations in Liopetri Bay, sampled from May 1997 - June 1999.

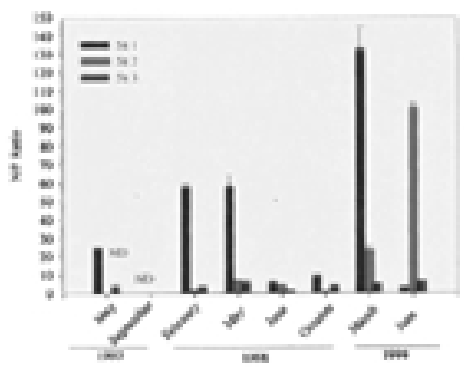

Figure 2. Nitrogen/Phosphorus (N/P) ratio from the three stations in Liopetri Bay, sampled from May 1997 - June 1999. (ND = No Data).

CONCLUSIONS

On the basis of this study the conclusions are:

1. Enhanced nutrient inputs and particularly nitrates, stimulated the nuisance growth of Cladophora spp. at the vicinity of the hatchery, and then extended in the Bay predominantly by the wind-driven currents. 2. Cladophora spp. continued proliferation in the Liopetri Bay may be fuelled by the cumulative nutrient inputs from the different sources found in the area, among those the groundwater horizon seepage, domestic effluents and the open sea fish-cages. 3. The potential impact from the groundwater seepage, domestic effluents and the open sea fish-cages to the Bay needs to be investigated. 4. Cladophora spp. after its introduction/appearance to the marine environment of Cyprus has become a part of the ecosystem and therefore, every year occurred in «normal» densities along most of the coasts of Cyprus. 5. In the presence of excess nutrient inputs and the interaction with other environmental factors Cladophora spp. can reach nuisance blooms.

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