

Monitoring of *Caulerpa taxifolia* (Vahl) C. Agardh and *Caulerpa racemosa* (Forskaal) J. Agardh in Tunisia: Strategy and results

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Abstract

Accidentally introduced into the Mediterranean Sea in 1984, the tropical alga *Caulerpa taxifolia* has spread since then, reaching the Tunisian coast. Another variety of *Caulerpa racemosa* (*Caulerpa racemosa* var *occidentalis*) was discovered in Tunisia and qualified as invasive. The ecological and economic threats related to these invasions led us to adopt a strategy of monitoring our littoral. This paper describes this strategy and summarizes the ensuing results.

1. Introduction

Given the phenomenon of the introduction of exotic species into the Mediterranean, and following the coastal States' concerns about the recent accidental introduction of the green alga *Caulerpa taxifolia* (Vahl) C. Agardh in 1984 (Meinesz and Hess, 1991), the UNEP organized a workshop on the invasive *Caulerpa* species in the Mediterranean (UNEP, 1999). Among the conclusions on which all present agreed were:

- *Caulerpa taxifolia* is a tropical species, observed for the first time in the Mediterranean Sea in Monaco in 1984. Since then it has expanded, covering large areas of the Western Mediterranean and of the Adriatic coastal region. At the same time, another *Caulerpa* species, *C. racemosa* (Forskaal) J. Agardh, expanded in many parts of the Mediterranean.
- *Caulerpa taxifolia* has been studied extensively in the Mediterranean, as its impact on the marine ecosystem is well admitted. It colonizes all types of sea bottoms such as, rock, sand, mud and dead *Posidonia* meadows, and invades indigenous biocenoses, modifying the biodiversity and the ecodiversity.
- *Caulerpa racemosa* has not been studied intensively, like *C. taxifolia*, but it is becoming clear that it may present different morphological characteristics from one region to another, that it colonizes all types of substrata such as, rock, sand, mud and dead *Posidonia* meadows, down to 60 m depth and interferes with marine coastal biocenoses, and that its expansion, according to preliminary research, may alter marine habitats.

Taking into account the Protocol of the Barcelona Convention concerning Specially Protected Areas and Biological Diversity in the Mediterranean (1995), which states that the Parties shall take "all appropriate measures to regulate the intentional or accidental introduction of non-indigenous or genetically modified species ... and prohibit those that may have harmful impacts on the ecosystems or species" and endeavour "to implement all possible measures to eradicate species that have already been introduced when, after scientific assessment, it appears that such species cause or are likely to cause damage to ecosystems, habitats or species in the area to which this Protocol applies", it was recommended that all the

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Mediterranean countries, besides adopting the necessary measures for the application of the Convention on Biological Diversity adopted at Rio de Janeiro in 1992 and of the Protocol of the Barcelona Convention (1995), and prohibiting trade and use of *C. taxifolia* and *C. racemosa* and avoiding the sale and use of the *Caulerpa* genus for aquaria (with the exception of the Mediterranean species *Caulerpa prolifera*):

- Promote national and international coordination and cooperation of all the partners to prevent and slow down the spread of *C. taxifolia* and *C. racemosa* in the Mediterranean
- Support international programs for the exchange of information, training and scientific research
- Support the dissemination of information designed to encourage users of the sea to prevent the spread, and indicate the presence, of *C. taxifolia* and *C. racemosa* and
- Issue official instructions calling upon users of the sea to indicate the presence of *C. taxifolia* and *C. racemosa* to the designated bodies.

Similarly, it was recommended that all the countries in which one or both of the two *Caulerpa* are present

- Issue official instructions for all users of the sea to avoid practices contributing to the spread of these species, particularly through the cleaning of anchors, fishing gear and diving equipment on the spot. The release of fragments of these algae at sea must be avoided. Large colonized areas should be indicated in port offices and nautical instructions
- Establish inventories and carry out cartographic surveys of colonized areas and monitor the evolution of the biocenoses in these zones
- Support scientific research in all aspects relating to these species, the understanding of the phenomenon, the evolution of its consequences and the control of its dynamics
- Control, where possible, the expansion of the two species, particularly by eradicating small colonies in areas that are highly valued for their natural heritage and regions that are distant from strongly colonized areas.

The first step towards the implementation of an international strategy is thus to sensitize and inform scientists and the decision-makers in the various Mediterranean countries. The Heraklion workshop was, as such, decisive.

2. Strategy of monitoring and control of Tunisian coasts

Signatory to all the conventions related to marine biodiversity preservation, Tunisia has since 1997 adopted prevention measures and a strategy to monitor and control its coasts. Since then, this strategy has been revised and at present consists of:

a) Information and sensitization

The general public is often confused and bewildered by some sensational press articles and by certain declarations that have appeared in the various media. To cure this, a leaflet on *Caulerpa taxifolia*, answering in a simple and non-alarmist way to the questions put by the general public, was realized by scientists. In this leaflet, a drawing of the alga is given to facilitate its identification and modes of its dissemination are described. Up-to-date

knowledge on its environmental impact is summarized and action to undertake against a discovered colony described. Anyone recognizing or believing s/he recognizes the alga is invited to contact the organization monitoring the expansion of the alga along the Tunisian littoral (the National Institute of Marine Sciences and Technologies: INSTM), by phone (the phone number appears on the leaflet) or by returning a coupon attached to the leaflet and pre-addressed to the INSTM, after filling it with some basic information related to the observations (substrata, distance from the coast, etc.).

This leaflet was published in Arabic and in French, with 10,000 copies (5,000 for each language) in 1997 (Langar *et al.*, 1998) and republished after revision with 5,000 copies in Arabic in 2000. It was widely distributed to all the users of the sea (divers, spear fishers, fishermen, sailors, bathers, harbour offices, etc.) and placed at the disposal of the public in the oceanographic museum and diving and fishing equipment stores.

To attract a wider public, parallel actions were carried out to help spread the information. Several conferences on *Caulerpa taxifolia* and *Caulerpa racemosa* were held in various ports and diving clubs. An Arabic translation of an IFREMER video film on *Caulerpa taxifolia* was made and broadcast to the general public at marine environment demonstration events. Several articles approved by scientists appeared in national newspapers and several interviews in relation to exotic algae were given to the national and regional radios.

b) Verification of information

All information that reaches us, either by telephone or by mail, is taken into account. In each case direct contact is made to verify some points permitting to guarantee that there is no confusion with another alga. If the verification reveals a mistaken identification of the alga, information is not taken into consideration. In the opposite case a diving visit is necessary to verify the information. Once the information validated, and if it is proved that the zone where the alga is present is relatively large, an underwater prospecting campaign is conducted in the area to map or to define the extent of the concerned area.

c) Centralization of the Information and decision-making

All information and data are centralized within the INSTM team in charge of the monitoring program for introduced algae in Tunisia. This team regularly gives an account of its activities and results to an interdepartmental national commission for introduced marine species that was created in 2000 under the presidency of the INSTM. This commission, judging facts presented by scientists, studies all possible proposed solutions, makes recommendations to the competent bodies and acts to justify for decision-makers the funding of research programs dedicated to the introduced species.

d) Publishing of scientific results

All research works leading to original results are published at national or international level, in scientific magazines and proceedings of symposia. The sensitisation and the vulgarization aspects were the subject of two publications in two proceedings of symposium (Langar *et al.*, 1998; Djellouli *et al.*, 1999). Identification of sites, biogeography and mapping of *Caulerpa* produced 5 communications at various scientific meetings (Djellouli *et al.*, 1998; 1999; Djellouli, 2000; Langar *et al.*, 2001; Langar *et al.*, 2003) and two scientific publications (Langar *et al.*, 2000; Langar *et al.*, 2002). The growth dynamics of *Caulerpa taxifolia* and its impact on *Posidonia* meadows in the roadstead of Sousse were presented at Mediterranean level (Langar *et al.*, 2003) and the impact of *Caulerpa taxifolia* on fishing outputs and on the socio-economy are the main subject of a recent paper (Ben Salem and Gaamour, in this issue).

3. Results and discussion

Since the first sensitization campaign in 1997 (Langar *et al.*, 1998), three sightings were verified in the field, one in the roadstead of Sousse in 2000 (Eastern coast of Tunisia) (Langar *et al.*, 2000), and two others in the area of Cap Bon (North-East Tunisia) in 2001 and 2002. Underwater mapping performed in the roadstead of Sousse revealed an area of 350 ha where *Caulerpa taxifolia* was present (Langar *et al.*, 2001). In the area of Cap Bon, sightings were made by nearly 40 m depth that did not permit us to achieve direct underwater mapping of the area. This is why a rough delimitation of the concerned zone was made with the help of fishermen interviews. The map produced (Fig. 1) revealed a vast zone where *Caulerpa taxifolia* was present, from Sidi Daoud to Ras Adar by -15 to -45 m, along 15 km of coast.

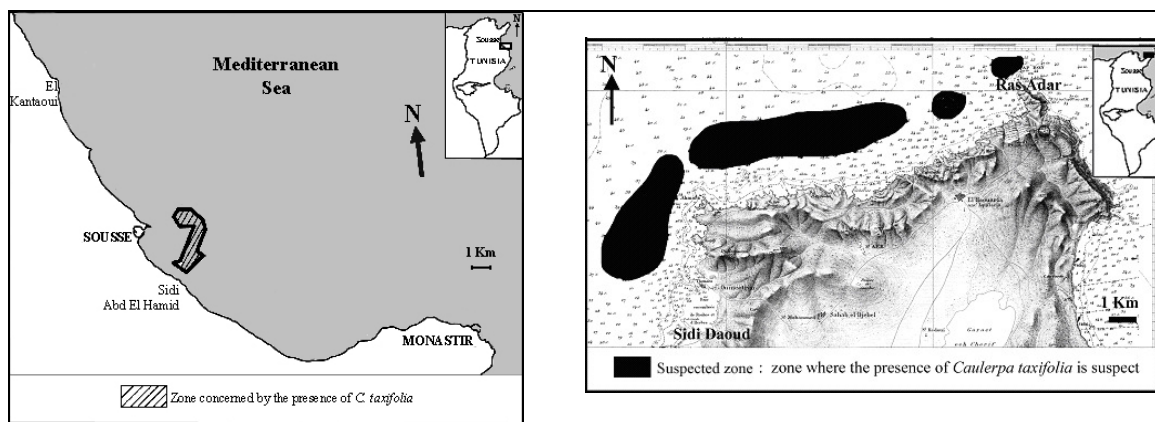


Figure 1: *Caulerpa Taxifolia* situation in the roadstead of Sousse (left) and in the Cap Bon area (right)

Caulerpa racemosa was identified along nearly the entire Tunisian coast, in 15 localities (Figure 2). Two varieties of *Caulerpa racemosa* were identified: the *uvifera* variety and the *occidentalis* one qualified as invasive.

In the light of this, the interdepartmental national commission in charge of the introduced marine species recommended applying the fishing and anchoring closure to the roadstead of Sousse, and worked to free a financing of 100,000 euros to acquire underwater prospecting equipment (ROV and accessories). Similarly, a research program has been financed; its main goals are to localize new sites contaminated by the introduced alga, to map them if possible, to follow the kinetics of *Caulerpa taxifolia* growth in Tunisian environmental conditions and

to study impacts of the introduced *Caulerpa* on biodiversity and more especially on the benthic macro flora, on fishing outputs and on the socio-economy. The more recent results are those concerning the impact of *Caulerpa taxifolia* on fishing outputs and on the socio-economy (Ben Salem and Gaamour, in this issue) and the kinetics of growth and the impact of *Caulerpa taxifolia* on *Posidonia* meadows in the conditions of the roadstead of Sousse. This later work showed that in conditions of the roadstead of Sousse, where the temperature falls rarely below 15 °C, the potentialities of growth of *C. taxifolia* does not seem different from those described in the conditions of the north-west Mediterranean (Meinesz *et al.*, 1997): a colony of 700 cm² reaches 7.25 m² in 2 years. *Posidonia* bed seems to resist to *C. taxifolia* the first year of contact and is invaded more easily from the second year of contact. The impact of *C. taxifolia* on the degraded *Posidonia* meadow, in the conditions of this work, is close to that described in the conditions of the north-west Mediterranean (Meinesz *et al.*, 1997).

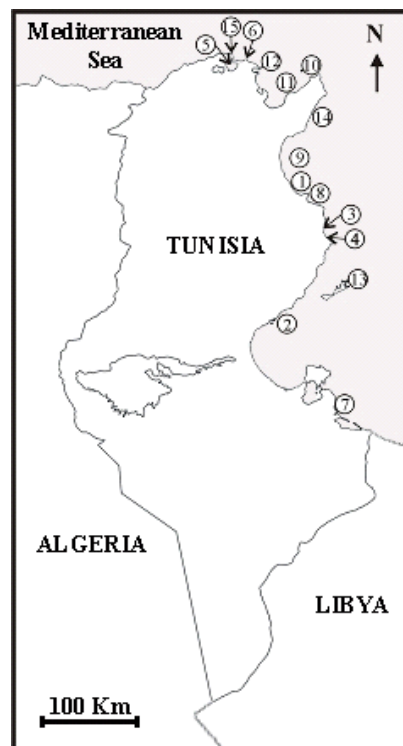


Figure 2 : Distribution of *Caulerpa racemosa* in Tunisia: (1) Sousse harbour; (2) Golf of Gabes; (3) Mahdia harbour; (4) Salakta; (5) Lagoon of Bizerte; (6) Cani Islands; (7) Zarzis; (8) Monastir; (9) Hammamet; (10) Sidi Daoud; (11) Sidi Raïs, Korbous and Ras Fartas; (12) Metline and Rafraf; (13) Kerkennah Islands; (14) Beni Khia; (15) Bizerte

4. Conclusion

Official communication campaigns and prevention measures are cost-effective means to partly control the spread of exotic algae. The fact that only one organization collects the data avoids loss of information.

The official quality of the scientific team in charge of the monitoring, and the involvement of all the governmental bodies in managing the crisis implies that any decision is well considered and takes into account concern for the conservation of biodiversity and socio-economic consequences. Communication and cartography campaigns remain the basis for research. They must be the main objectives of *Caulerpa* monitoring and control projects.

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