



Caulerpa taxifolia, a growing menace for the temperate marine environment

For the first time in history, a genetically altered seaweed is colonising very large areas of the marine environment in an uncontrollable way. The green alga, mutated by exposure to chemicals and ultraviolet light, has shown dangerous capabilities allowing it to adapt, colonise, and threaten multiple biotopes.

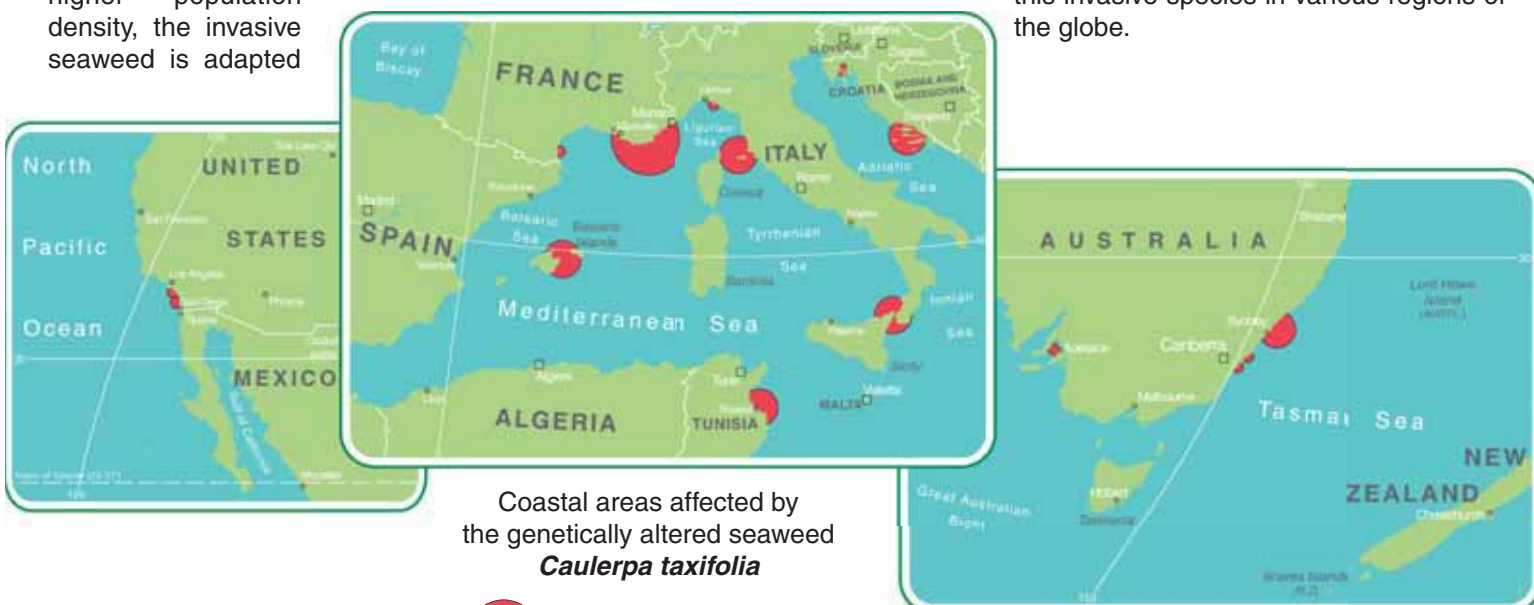
Current situation

Caulerpa taxifolia is a fast growing marine seaweed that is originally only found in warm tropical waters (Caribbean coasts, Gulf of Guinea, Red Sea, East African coast, Maldives, Seychelles, northern Indian Ocean coasts, southern China Sea, Japan, Hawaii, Fiji, New Caledonia, and North Australia). It has been used widely as a decorative plant in the marine aquarium trade.

Around 1984, a genetically altered type of *Caulerpa taxifolia*, with unusual morphological and physiological characteristics, was accidentally released into the Mediterranean Sea. Apart from larger and longer fronds and a higher population density, the invasive seaweed is adapted

to a larger spectrum of temperatures, and a higher concentration of toxic metabolites than tropical populations. Today, this seaweed has invaded over 30 000 ha in the Mediterranean basin and has also colonised Southern Australia and the western coast of the United States (see maps below).

The alga, forming dense carpets, is out-competing native seaweeds and leading to a loss of biodiversity. Local activities are suffering from this threat to eco-diversity; recreational diving, tourism in general and the fishing industry are already affected by the introduction of this invasive species in various regions of the globe.



- More than 10 000 ha affected
- More than 500 ha affected
- Local observation



History

In the early 1980's, the curator of the tropical saltwater aquarium at the Wilhelmina Zoo in Stuttgart (Germany), noticed the exceptional properties of a bright green alga, *Caulerpa taxifolia*, used as tank decoration. There, it was bred by the aquarium staff and exposed for years to chemicals and ultraviolet light. This exposure to abiotic stressors altered and switched on genes that were not previously present, expressed or active in wild type strains (¹Madi P. & Yip M., 2003). The genetically altered seaweed, in contrast to wild types, grows with astounding vigour even in cool water temperatures. Specialists quickly learned about these qualities, and public aquaria around the globe acquired cuttings, since the alga can only be propagated vegetatively.

Caulerpa racemosa, the grape algae

Caulerpa taxifolia is not the only invasive species of this genus spreading in the Mediterranean Sea. While *Caulerpa taxifolia* has been accidentally released from an aquarium, *Caulerpa racemosa* is considered to have migrated from the Red Sea through the Suez Canal on ships' hulls or in ballast water (²Meinesz A., 2003).



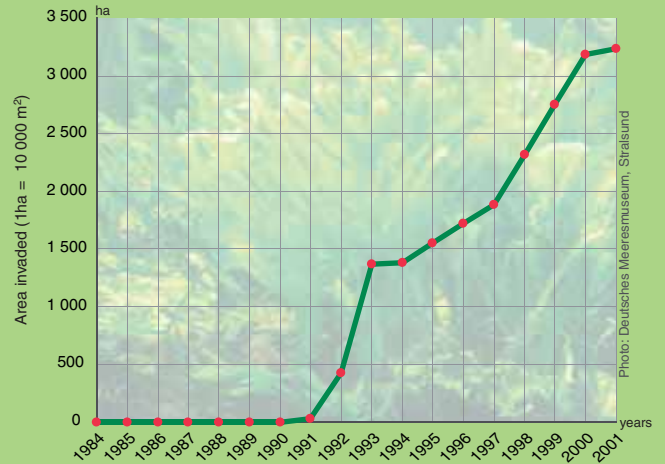
Photo: F. Javel, LEMV

Recent genetic analyses have shown that this *Caulerpa racemosa*, first spotted in Tripoli harbour (Libya) in 1990, originates from South Australia. It was first reported on the French coast in 1997. Its maximum biomass is much lower than *Caulerpa taxifolia*. Its fronds rarely exceed 10 cm in length, but it shares *Caulerpa taxifolia*'s great ability to cover the sea bed with its creeping network of horizontal stolons.

A serious increase in *Caulerpa racemosa* colonisation has been observed on the French coast. During 2002, 10 new colonised areas were reported, for an approximate total of 1 000 ha surface. *Caulerpa racemosa* is invading much faster than *Caulerpa taxifolia*. As it spreads into the western Mediterranean, it even seems to be capable of out-competing *Caulerpa taxifolia*!

Mapping *Caulerpa racemosa*'s expansion is difficult due to its ability to invade deeper areas rarely visited by free-divers and to its less noticable size and colour. Moreover data on its expansion are rapidly obsolete due to the speed of its invasion. This can be explained by its very efficient reproduction, both sexual and through propagules, never seen with *Caulerpa taxifolia*.

Growth in area invaded by *Caulerpa taxifolia* on French and Monaco coast⁽³⁾



In 1984, a professor at the University of Nice-Sophia Antipolis (France), observed a patch of *Caulerpa taxifolia* about one square meter in size located just in front of the Oceanographic Museum in Monaco where it had been released after aquarium cleaning (²Jousson O. et al, 2000). Genetic analysis of samples showed that this was the genetically altered aquarium type and not the result of natural dispersion. Since then the alga has colonized huge areas and is still progressing unchecked into new habitats. The modified algae grow everywhere, from the surface to the lower limits of underwater vegetation, from rocky capes swept by storms and currents to the soft bottoms of sheltered bays, from the polluted mud of harbours to bottoms with a diverse flora and fauna. With its cocktail of highly toxic chemical defences, it is barely eaten by herbivores, facilitating its limitless spread. It is thus growing unrestrained, covering and then eliminating many native plant and animal species.

Photo: Y. Gladu, UPC



Consequences

The rapid expansion of *Caulerpa taxifolia* along the French Mediterranean coast, where the introduction was first reported, has been associated with urban wastewater pollution. It easily multiplies through vegetative spreading aided by dispersal via anchors and fishing nets, or dumping ballast water, in particular in harbours, marinas and other places where boats anchor. Currents spread this species more widely by transporting fragments to colonize new areas (Chrisholm et al, 1997). Apart from shipping, the long-range dispersal of this alga was facilitated by the world-wide aquarium trade.

Its chemical defence mechanism (the alga produces repellent toxins) renders it unpalatable to generalist herbivores, facilitating this biological invasion. *Caulerpa taxifolia* is upsetting the ecosystem by invading and out-competing the native flora while protecting itself against predation, thus threatening the biological stability of the marine environment. With its spectacular average growth rate of 1 cm per day, the seaweed becomes a major threat to protected habitats such as eelgrass, the essential living and breeding habitat of various species. Most of the indigenous algae regress and tend to disappear. The species composition of microscopic fauna and macrofauna is strongly modified. The fish species number, the number of individuals, the biomass and the mean weight are significantly lower in habitats colonised by *Caulerpa taxifolia*. Finally, it is reported to have harmed tourism, pleasure boating and recreational diving, and had a costly impact on commercial fishing both by altering the distribution of fish as well as interfering with fishing nets.

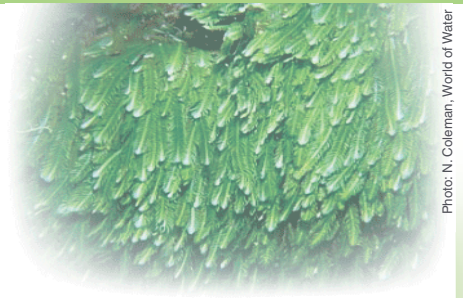
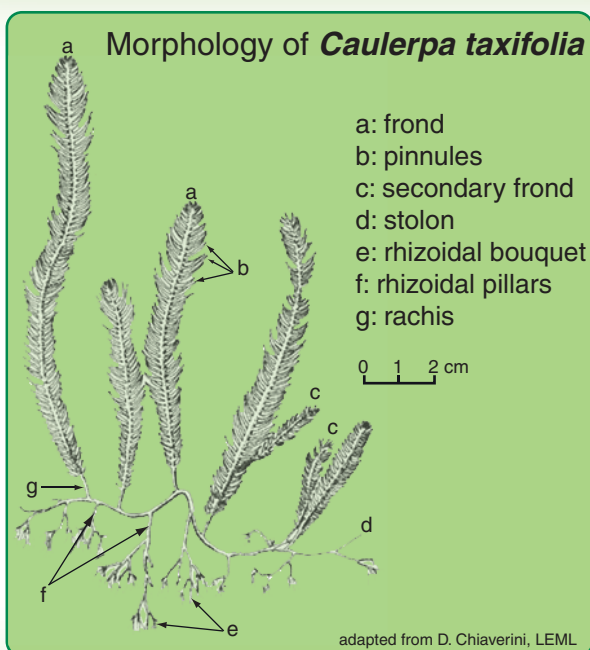


Photo: N. Coleman, World of Water



Action !

A number of eradication methods have been tested: manual removal of the plants, suction pump, hot water, electrolysis with copper electrodes, copper ions through an ionic selective membrane, and the use of chlorine. The biological control by molluscs and nudibranchs is in an experimental phase, but introducing some grazing tropical species in temperate waters might lead to unexpected consequences. Manual eradication by divers, implemented at Mallorca in the Balearic Islands (Spain) and Port-Cros (France) is another technique which has been effective against populations covering a small area.

An efficient method has been used for the last five years in the San Diego (USA) area to treat the seaweed in situ to avoid further fragmentation and spread. Each patch of *Caulerpa taxifolia* was covered with a heavy plastic sheet that was sealed to the bottom at the edges and fitted with a small "port" on top that allowed for the introduction of herbicide under the sheet. The plastic allowed for the direct treatment

of the target patch, while preventing the loss of herbicide to the lagoon waters.

These techniques can only be applied to very local settlements of *Caulerpa taxifolia*, and large-scale eradication remains far out of reach with current means. Monitoring and public awareness programs are the only effort made so far by the concerned countries. It seems that control of the invasion was and still is not a priority for most of them. The result is the colonisation of a great number of areas by this seaweed and a new threat for marine biodiversity. ♦

Caulerpa taxifolia legislation

In December 1994, scientists assigned to study the problem by the European Commission, issued the "Barcelona Appeal" calling the spread of *Caulerpa taxifolia* a major threat to Mediterranean ecosystems.

Within the Mediterranean basin, article 13 of the Barcelona Convention's Protocol on Specially Protected Areas, which was adopted in 1996, provides legislation regarding the introduction of non-native species like *Caulerpa taxifolia*.

In March 1998, at UNEP's "Workshop on the Caulerpa Species Invasive in the Mediterranean" held at Heraklion, Crete, representatives unanimously concluded that the alga constitutes a major threat to Mediterranean ecosystems and recommended that all affected countries establish a strategy to prevent dissemination and curb the invasion.

Following this, several governments or regional entities affected by the alga, adapted their legal system to ban selling, buying, using and dumping of any part of the species.


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"Les Dossiers d'Info Science" at http://www.infoscience.fr/dossier/caulerpa/caulerpa_som.html
"Le Groupement d'Intérêt Scientifique Posidonie" at <http://www.com.univ-mrs.fr/gisposi>

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