Caulerpa taxifolia

System: Marine

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<th>Kingdom</th>
<th>Phylum</th>
<th>Class</th>
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<td>Plantae</td>
<td>Chlorophyta</td>
<td>Chlorophyceae</td>
<td>Caulerpaless</td>
<td>Caulerpaceae</td>
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Common name
Schlauchalge (German), lukay-lukay (English, Philippines), sea weed (English), killer alga (English), caulerpa (English)

Synonym
Fucus taxifolius, Vahl, 1802

Similar species
Caulerpa mexicana, Caulerpa prolifera, Caulerpa racemosa, Caulerpa veravalensis

Summary
Caulerpa taxifolia is an invasive marine alga that is widely used as a decorative plant in aquaria. A cold-tolerant strain was inadvertently introduced into the Mediterranean Sea in wastewater from the Oceanographic Museum at Monaco, where it has now spread over more than 13,000 hectares of seabed. Caulerpa taxifolia forms dense monocultures that prevent the establishment of native seaweeds and excludes almost all marine life, affecting the livelihoods of local fishermen.

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Species Description
Caulerpa taxifolia is a light green macroalga with upright leaf-like fronds arising from creeping stolons. The fronds are flattened laterally and the small side branchlets are constricted at the base (where they attach to the midrib of each frond), are opposite in their attachment to the midrib (as opposed to alternating) and curve upwards and narrow towards the tip. The invasive aquarium clone is morphologically identical to native populations of the species. Frond diameter is 6-8mm and frond length is usually 3-15cm in the shallows, 40-60cm in deeper situations but can grow up to 2.8m in height (NIMPIS, 2002). C. taxifolia is distinguished from other Australian Caulerpa species by the branchlets that are constricted at the base (where they attach to the midrib of each frond) and they are opposite in their attachment to the midrib (as opposed to alternating). Also, the branchlets curve upwards and taper at the apex (NIMPIS, 2002).
Notes
The cold-tolerant aquarium (Mediterranean) clone is the invasive strain of this species, and is therefore referred to as *Caulerpa taxifolia* in this profile. It was introduced to the Mediterranean in wastewater from the Oceanographic Museum at Monaco where it now covers over 13,000 hectares of seabed along 190km of coast. An invasive tropical strain has also been discovered near Sydney, Australia (Nova, 2003) and invasions were also detected in southern California (Williams & Grosholz, 2002). Genetic analysis has revealed that the *C. taxifolia* strains found in California are identical to those found in the Mediterranean and in many aquaria. They are also very similar to plants found in southern Australia, leading to the hypothesis that the invasive strain originated from Australia and was distributed via the aquarium trade to many parts of the world (Meinesz et al., 2001b).

In the Mediterranean Sea, the molluscs *Oxynoe olivacea* and *Lobiger serradifalci* are found on *C. taxifolia* and feed on it. The grazing rate of these two ascoglossans is low and significantly effected by temperature. *Elysia subornata* is an opisthobranch that feeds only on species of *Caulerpa* and is a potential for biological control of *C. taxifolia* in the Mediterranean. During summer and autumn, the toxic substance produced by *C. taxifolia*, caulerpenyne, may be the reason there are few consumers (NIMPIS, 2002).

Research on the Mediterranean and tropical strains of *C. Taxifolia* revealed some major differences between them. The Mediterranean strain has larger fronds, lacks female gametes, can withstand lower temperatures, and has increased concentrations of defensive chemical metabolites (Raffaelli et al., 1997).

*C. Taxifolia* appears to have been distributed around the Mediterranean as fragments attached to ship anchors, as the locations of new outbreaks are predominantly associated with port and mooring facilities (Meinesz et al., 2001b).

Observation of native populations of *C. Taxifolia* growing at temperatures of 9 to 11°C in Moreton Bay, Australia, has raised doubts over whether the Mediterranean populations are of a genetically-modified, cold-adapted strain, as has been asserted by some authors (Phillips & Price, 2002).

Lifecycle Stages
Monoecious. In the Mediterranean reproduction is vegetative by fragmentation. In native populations, male and females gametes fuse forming a zygote which grows through two little known stages prior to becoming the adult (NIMPIS, 2002). Sexual reproduction has been observed in central Queensland. Gametes released in June - September in Adriatic Sea (NIMPIS, 2002).

Uses
Widely used as a decorative plant in private and public saltwater aquaria (Meinesz et al., 2001b).
Habitat Description
Found on a wide variety of substrates from rock, sand and mud to seagrasses. It is usually found in depths of 3-35m, but has been recorded at depths down to 100m in the Mediterranean. The invasive aquarium strain is able to occupy up to 100% of the available substratum. Native populations in tropical waters are found on rocky reefs and seagrass meadows in sheltered or moderately wave-exposed areas in both polluted and pristine waters (NIMPIS, 2002). The temperature range for the Mediterranean strain is 7°C - 32.5°C, while the maximum salinity is 38 ppt (NIMPIS, 2002).

Reproduction
Native populations of *C. taxifolia* are known to reproduce sexually, however the aquarium strain is apparently an all-male clone (only producing male gametes). In the Mediterranean the aquarium strain spreads vegetatively by growth of the stolons or by regeneration from broken off fragments as small as 1 square centimetre in size (NIMPIS, 2002). The minimum reproductive temperature has been recorded as 25°C for all-male clones in the Adriatic Sea (NIMPIS, 2002).

Nutrition
*Caulerpa taxifolia* gains nutrition through photosynthesis.

General Impacts
The *Caulerpa taxifolia* aquarium strain in the Mediterranean Sea is extremely invasive and smothers other algal species, seagrasses and sessile invertebrate communities. It does this by either out-competing species for food and light or due to the toxic effects of its caulerpenyne compounds. Its large monospecific meadows have vastly reduced native species diversity and fish habitat (NIMPIS, 2002). Effects on humans are mostly related to the reduction of catches for commercial fishermen due to the elimination of fish habitat by *C. Taxifolia*, although the entangling of nets and boat propellers with this weed also affect efficiency (NIMPIS, 2002). Fish which are able to eat *C. Taxifolia*, such as the Mediterranena bream (*Sarpa salpa*), accumulate toxins in their flesh that make them unsuitable for human consumption (Meinesz & Hesse, 1991). *C. Taxifolia* outcompetes the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* in Mediterranean ecosystems (NIMPIS, 2002).

Economic impacts resulting from the cost of eradication included approx $US6 million spent in Southern California up to 2004 (Anderson, 2004) and $AUS6-8 million in South Australia.
Management Info

Preventative measures: Nyberg and Wallentinus (2005) state that Caulerpa taxifolia is one of five top risk species in Europe. The authors study quantitatively ranked species traits which facilitate introduction and predominance using interval arithmetic to search for common patterns among 113 marine macroalgae introduced in Europe. From the abstract Nyberg and Wallentinus (2005) “Three main categories were used: dispersal, establishment and ecological impact. These were further subdivided into more specific categories, a total of 13. Introduced species were compared with the same number of native species randomised from the same families as the introduced. Invasive species (i.e. species having a negative ecological or economical impact) were also compared with non-invasive introductions, separately for the three algal groups. In many categories, as well as when adding all species, the introduced species ranked more hazardous than the native species and the invasive species ranked higher than the non-invasive ones. The ranking within the three main categories differed, reflecting different strategies between the species within the three algal groups. When all categories (excluding salinity and temperature) were summed, the top five risk species, all invasive, were, in descending order, C. fragile spp. tomentosoides, Caulerpa taxifolia, Undaria pinnatifida, Asparagopsis armata and Grateloupia doryphora, while Sargassum muticum ranked eight and Caulerpa racemosa ten. Fifteen of the twenty-six species listed as invasive were among the twenty highest ranked”.

Chemical: Colonies of C. taxifolia that were discovered in Southern California were eradicated by covering and sealing them with PVC tarpaulins and injecting liquid chlorine underneath. Subsequent treatments at another location used solid chlorine formulations (Anderson & Keppner, 2001). Costs of the Southern Californian eradication were $US2.33 million from 2000-01 for control and monitoring (Carlton, 2001), with an ongoing annual surveillance cost of $US1.2 million until 2004 (Anderson, 2004).

Application of coarse sea salt at a concentration of ~50kg/m² has been used with moderate success in Australia, eradicating C. taxifolia from an area almost 5200 m² in one case, although in another case an area of 3000 m² showed a reduction in algal density but eradication was not achieved. The use of this method in the cooler months, when C. taxifolia naturally dies back, was recommended. Salting has so far only been successfully used on soft sediments in water <6m in depth (Glasby et al, 2004).

Physical: Simply covering C. Taxifolia colonies with black PVC plastic was found to be reasonably successful in Croatia. A total area of 512 m² was treated, with either no or sporadic regrowth occurring after treatment (McEnnulty et al, 2001).

Manual removal by scuba divers was successful in eradicating a small patch of C. Taxifolia, around 3.4 m², in the French Mediterranean. The use of a suction pump to remove all fragments has also met with moderate success in other areas. Clearance rates for manual removal are from <1 m² to ~3 m² per diver per hour (McEnnulty et al, 2001).

Pathway

Cuttings can be distributed over long distances by boat anchors or fishing nets. Used as an ornamental species in home and public aquaria. Caulerpa taxifolia has established in a number of locations as the result of improperly disposed waste from aquaria. Cuttings can be distributed over long distances by boat anchors or fishing nets.

FULL ACCOUNT FOR: Caulerpa taxifolia

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Review: Dra. M? Antonia Ribera, Laboratory of Botany, Faculty of Pharmacy, University of Barcelona, Spain.

Publication date: 2006-04-18

ALIEN RANGE
[6] AUSTRALIA
[3] CROATIA
[1] FRANCE
[1] GERMANY
[5] ITALY
[1] MEDITERRANEAN & BLACK SEA
[1] MONACO
[1] NEW ZEALAND
[1] SPAIN
[4] UNITED STATES

BIBLIOGRAPHY
47 references found for Caulerpa taxifolia

Management information

Summary: Rapid response report for Caulerpa taxifolia in California.


Summary: An abstract about the eradication of C. taxifolia in Southern California.

Summary: Information on the eradication of C. Taxifolia in California.
Available from: http://www.anstaskforce.gov/ANS%20Digest%204_2.pdf


Summary: This book includes a synthesis of results of the CE- LIFE Program Spreading of the tropical seaweed Caulerpa taxifolia in the Mediterranean and the 46 lectures presented on the First International Workshop on Caulerpa taxifolia.


Summary: This publication contains the bibliographic references of 358 documents and scientific papers about Caulerpa taxifolia invasion in the Mediterranean Sea.


Summary: An overview of many introduced marine species in the U.S.

Summary: A small amount of information on the cost of eradicating C. taxifolia from the West Lakes in Adelaide, South Australia.


Summary: Growth, survival, reproduction.

European and Mediterranean Plant Protection Organization (EPPO), 2006. Guidelines for the management of invasive alien plants or potentially invasive alien plants which are intended for import or have been intentionally imported. EPPO Bulletin 36(3): 417-418.

Summary: Seasonal light requirements and temperature tolerance of the Mediterranean C. taxifolia were examined by means of photosynthetic assays. These results indicate that this species is well adapted to light and temperature typical of the infralittoral and upper circalittoral zone in the Mediterranean. Its annual productivity pattern seems less affected by seasonal fluctuations than has beeb reported for endemic seaweeds; this response may explain its potentially high invasive capacity.

Summary: Information on the use of salting to control C. taxifolia.


Summary: Contains management information.


Summary: Report on the expansion of Caulerpa taxifolia in the Mediterranean coasts at end of 1997: 5 countries affected, 99 stations cited, 4630 ha concerned, 81 km of coast affected. The report included the cartography of the C. taxifolia populations in each station.


Summary: Links are provided from the species summary page to more information on Common Names, Synonyms, Identification Notes, Similar Species, Morphology, Reproduction, Life Cycle, Habitat, Survival, Food, Competitors, Predators, Impact information, Vectors, Dispersal, Control options and additional information.

NIMIPS is available from: http://www.marine.csiro.au/crimp/nimips/

Summary: The National Pest Plant Accord is a cooperative agreement between regional councils and government departments with biosecurity responsibilities. Under the accord, regional councils will undertake surveillance to prevent the commercial sale and/or distribution of an agreed list of pest plants.


Summary: This book includes a synthe of results of the CE-LIFE Program Spreading of the tropical seaweed Caulerpa taxifolia in the Mediterranean and the 54 lectures presented on the Second International Workshop on Caulerpa taxifolia.


Summary: Possible biocontrol has been found for Caulerpa. Available from: http://massbay.mit.edu/publications/marinebioinvasions/mbi2_abstracts.pdf [Accessed 23 January 2009]


Summary: A review of management techniques used for invasive marine species.


Williams, Erin & Edwin Grosholz (Eds) 2002. International Caulerpa taxifolia Conference Proceedings January 31 ? February 1, 2002 San Diego, California, U.S.A. Hosted by the University of California Cooperative Extension With Support From: California Department of Fish & Game California Sea Grant College Program U.S. Fish & Wildlife Service, Aquatic Nuisance Species Task Force Proceedings Assistance Provided by: California Sea Grant College Program

Summary: The proceedings include summary papers containing both previously published and unpublished work on a wide range of issues concerning the invasion of Caulerpa and issues concerning similar invasive species and their habitats. The Editors have attempted to put together all the information presented in a way that accurately reflects how this information was presented at the conference. They hope that this information will help guide future eradication efforts in both the U.S. and elsewhere.


Summary: Reports on in situ observations of a C. taxifolia invasion in Huntington Harbour, California.


General information

Bienvenue sur le portail Caulerpes

Summary: Up-to-date information on the distribution of C. taxifolia in the Mediterranean and worldwide. Contains a dynamic distribution map of the Mediterranean and is available in both French and English. Available from: http://www.caulerpa.org


Summary: This is a synthese of the knowlege on the ecology, biology, toxicity, impacts and management of the Mediterranean populations of Caulerpa taxifolia. And it concludes that if Caulerpa taxifolia continues to spread at present rates we will witness a major ecological event, with a strong decrease of eco-diversity, in the Mediterranean coastal waters.
The species list sheet for the Mexican information system on invasive species currently provides information related to Scientific names, family, group and common names, as well as habitat, status of invasion in Mexico, pathways of introduction and links to other specialised websites. Some of the higher risk species already have a direct link to the alert page. It is important to notice that these lists are constantly being updated, please refer to the main page (http://www.conabio.gob.mx/invasoras/index.php/Portada), under the section Novedades for information on updates.

Invasive species - Algae is available from: http://www.conabio.gob.mx/invasoras/index.php/Species_invasoras_-_Algas

[Accessed 30 July 2008]

Summary: The Caulerpa taxifolia of Cap Martin (France) contains the known sesquiterpenic toxins caulerpenyne and oxytoxin. Novel potentially toxic products isolated in small amounts from this seaweed include the sesquiterpenes taxifolial A, taxifolial B, 10,11 epoxycaul.


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Summary: AlgaeBase is a database of information on algae that includes terrestrial, marine and freshwater organisms. AlgaeBase is available from: http://www.algaebase.org; Caulerpa taxifolia information is available from: http://www.algaebase.org/SpeciesDetail.lasso?species_id=1413&-session=abv3:82D89F50cb2503A64PhW2DCE6D3 [Accessed 20 May 2005].

ITIS (Integrated Taxonomic Information System). 2004. Online Database Caulerpa taxifolia

Summary: An online database that provides taxonomic information, common names, synonyms and geographical jurisdiction of a species. In addition links are provided to retrieve biological records and collection information from the Global Biodiversity Information Facility (GBIF) Data Portal and bioscience articles from BioOne journals. Available from: http://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=6974 [Accessed December 31 2004]


Summary: The first molecular evidence that the tropical alga Caulerpa taxifolia escaped to the sea from a public or private aquarium is referred. These data show that this alga is genetically identical to the strain cultivated in western European aquaria since the early 1970 s.


Summary: The first record of Caulerpa taxifolia in Californian coasts is reported.


Summary: The first record of Caulerpa taxifolia in the Tunisian coast is reported.


Summary: The inhibition or delay of the proliferation of several phytoplanktonic strains by the action of organic extracts of Caulerpa taxifolia is reported. Seasonal variations of the toxicity were observed with a maximal effect in the summer.

**Summary:** The first record of *Caulerpa taxifolia* in the Mediterranean coasts is reported and the authors point out that the development characteristics of this population are different from those in its native tropical areas.


**Summary:** A paper looking at the distribution and spread of *C. taxifolia* in the Mediterranean Sea.


**Summary:** A review of the invasion of the Mediterranean by *C. taxifolia*. 


**Summary:** Contains the chronology of the *C. taxifolia* invasion in the Mediterranean and around the world. Available from: http://www.pbs.org/wgbh/nova/algae/ [Accessed on 7 December, 2004].


**Summary:** Information regarding the distribution of *C. taxifolia* within Australia.


**Summary:** A paper looking at differences between the chemical defences of the tropical and Mediterranean strains of *C. taxifolia*.


**Summary:** Has information on *C. taxifolia* distribution within Australia and the relationship between new occurrences and the invasive strain of this species.