ANNONATED BIBLIOGRAPHY FOR *CAULERPA TAXIFOLIA*

DRAFT

Sources: Agricola
USDA National Agricultural Library Database
Biosis
Science Citation Index
Internet

Containment/Chemical Treatment

Journal

Anderson LWJ

California's reaction to *Caulerpa taxifolia*: a model for invasive species rapid response

Biological Invasions 2005, 7:1003-1006

The Southern California *Caulerpa* Action Team (SCCAT) composed of state, federal, local and private groups was formed to combat the initial infestation of southern California waters with *Caulerpa taxifolia*. This task force was successful in eradicating *C. taxifolia* by implementing a very rapid response including containment and treatment of the invading population. It is suggested that such a rapid response may serve as a model for combating invasions by other noxious species.

Anderson LWJ, Tan W, Woodfield, Mooney R, and Merkel K

Use of sediment bioassays to verify efficacy of *Caulerpa taxifolia* eradication treatments

Journal of Aquatic Plant Management 2005, 43.

Sediment cores were collected from *C. taxifolia* infested areas after treatment with sodium hypochlorite. Cores were also collected from uninfested areas and inoculated with *C. taxifolia*. After two years, growth of *C. taxifolia* was not observed in the treated sediments. In the nontreated core, normal growth of *C. taxifolia* was apparent. In addition, eelgrass (*Zostera* marina L.) growth was observed in the treated cores.

Glasby TM, Creese RG, and Gibson PT

Experimental use of salt to control the invasive marine alga *Caulerpa taxifolia* in New South Wales, Australia

Biological Conservation 2005, 122:573-580

Sea salt at a concentration of 50 kg/m^2 was effective in killing *Caulerpa taxifolia* without producing irreparable harm to the ecosystem. The *C. taxifolia* population was decreased from 70-95% after 1 week and fronds were not detectable after 1 or 6 months. Though the native seagrasses were affected by the salt treatment, they fully recovered after 6 months.

Williams SL and Schroeder SL

Eradication of the invasive seaweed *Caulerpa taxifolia* by chlorine bleach

Marine Ecology Progress Series 2004, 272:69-76

C. taxifolia fragments were exposed to 0.02%, 0.03%, 0.10%, and 0.25% chlorine bleach at 20 to 23^{o}C and 10 to 11^{o}C (ambient seawater temperatures) or to temperature shocks of 7 to 10^{o}C and 72^{o}*C.* Treatments with 0.10% and 0.25% bleach after exposure times of as little as 30 min killed 60-100% of the fragments within 7 days and 100% by 14 days. These fragments did not exhibit any regrowth. Treatments with 0.02% and 0.03% bleach killed approximately 20%-50% of the fragments after 14 days. Regrowth from these fragments were up to 100% after 77 days. At 10 to 11^{o}C for all bleach concentrations, all fragments became chlorotic and exhibited no regrowth. When fragments were exposed to heat shock at 72^{o}C for 1 hr, all fragments were killed.

Withgott J

California tries to rub out the monster of the lagoon

Science 2002, 295:1

With the seaweed *Caulerpa* a global threat, the world is closely watching an eradication effort in California. The SCCAT or Southern California *Caulerpa* Action Team was formed without federal or state guidelines to prevent the type of catastrophe that *C. taxifolia* has caused in the Mediterranean. The main focus of SCCAT is a quick rapid response to control any *C. taxifolia* invasion.

Uchimura M, Rival A, Nato A, Sandeaux R, Sandeaux J, and Baccou JC

Potential use of Cu 2+, K + and Na + for the destruction of *Caulerpa taxifolia*: differential effects on photosynthetic parameters

Journal of Applied Phycology 2000, 12:15-23

Cu, K and Na were tested in their use for the control of *C. taxifolia*. Only Cu was determined to be suitable because both K and Na required too long of an incubation period and too high of a concentration for effective control. The effective rates for Cu, K and Na were 10 mg/l for 1 h, 20 g/l for 3 h, and 20 g/l for 1 h, respectively.

Meetings Abstracts/Symposium Proceedings

Creese B

Invasions of temperate waters by the tropical seaweed *C. taxifolia*: complexities, responses and ecological impacts

6th International Temperate Reefs Symposium 2003

C. taxifolia was found in 7 locations in New South Wales and 1 location in Southern Australia. It was considered to be a noxious weed in the southern part of Australia. Detailed mapping of the location of the alga was done and it showed that the spread of the alga could be reduced by the application of common salt.

Anderson LWJ

Caulerpa taxifolia in the United States: Rapid Response and Eradication Program

International Caulerpa taxifolia Conference Proceedings 2002

Within 2 weeks of the first sighting of *C. taxifolia* near Carlsbad, California in 2000, the Southern California *Caulerpa* Action Team (SCCAT) was formed and within 4 weeks eradication of the alga was initiated with the application of bleach on the bed of the alga. The SCCAT in 2001 was instrumental in the passage of a bill to ban *C. taxifolia* and 8 other species. SCCAT included participation from members of the following organizations: California Department of Food and Agriculture, California Department of Fish and Game, San Diego Regional Water Quality Control Board, US Department of Agriculture– Agricultural Research Service, and the National Marine Fisheries Service.

Anderson WJL

Caulerpa taxifolia in the United States: Rapid Response and Eradication Program

International Caulerpa taxifolia Conference Proceedings 2002

The Rapid Response and Eradication Program for the control of *C. taxifolia* in California was developed with the cooperation of multiple federal, state, local and private agencies and groups prior to the spread of this alga to the state. Steps in the program include tarping, restricting access, outreach, and surveillance. Therefore, when *C. taxifolia* was discovered, within two weeks an eradication program was implemented and the spread of the alga was inhibited.

Zuljevic A and Antolic B

Appearance and Eradication of *Caulerpa taxifolia* in Croatia

International Caulerpa taxifolia Conference Proceedings 2002

C. taxifolia invaded Croatia in 1991 and by 2001 had spread to 3 locations. Some distinct colonies were eradicated and were stopped from spreading using suction pumps and covering with black PVC foil. Eradication efforts were stopped in 1997 due to shortage of funds.

Newsletter

Jacoby C and Walters L

Can we stop "killer algae" from invading Florida?

Florida Sea Grant College Program SGEF-155

This leaflet was issued by the Florida Sea Grant College Program to educate the public about *C. taxifolia*. It described how not to spread the algae and speculate if it can be introduced into Florida's waters.

Fine P

Scientists try to put "killer algae" on ice

Trio - The Newsletter of the North American Commission for Environmental Cooperation 2003

C. taxifolia was discovered in Ague Hedonic Lagoon in Carlsbad, CA in Summer 2000. In response to this discovery, the Southern California *Caulerpa* Action Team (SCCAT) was formed. This patched was eradicated by Fall 2002 by covering the patch with PVC tarps and pumping chlorine into the tarps. This quick action led to successful removal of the *C. taxifolia*.

Stelljes KB

More troublesome water weeds targeted by researchers

Agricultural Research 2001: 7-9

An infestation of *C. taxifolia* in Huntington Harbor in Long Beach, CA was controlled with the application of chlorine bleach molded into solid puck shaped discs. Prior to the application of the bleach, the bed of *C. taxifolia* was covered with black plastic tarpaulins.

Report

Williams SL and Anderson LWJ

Research in Support of Management of *Caulerpa* invasions

CDFG Final Report 2003, 25 pp

The report summarizes the results of two years of independent research on *Caulerpa* to provide scientific information for the effective control of *C. taxifolia*. These include use of chemical eradication, development of models to predict potential spread, affect of light and temperature on the growth habits of the alga, tolerance to desiccation and tolerance to brackish and fresh waters.

Technical Report

Merkel & Associates (SCCAT)

Status Report: *Caulerpa taxifolia* invasions in Southern California

Status Report 2003

When *C. taxifolia* was first discovered in 2000 in Agua Hediona and Huntington Harbour Southern California, the response from the Southern California *Caulerpa* Action Team (SCCAT) was swift. The infested areas were covered with tarp and chlorine bleach was applied under the tarp. By Fall 2002, *C. taxifolia* was not detectable in Agua Hedionda and not detectable in Huntington Harbor by Winter 2002.

Merkel, K and Woodfield R

Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California

Second year status report 2003, 15 pp

This status report was prepared for the steering committee of the Southern California *Caulerpa* Action Team by Merkel and Associates. This described the eradication effort, status of the Lagoon and coordination of users and treatment efficacy. Future actions in the program were discussed.

Bourne P

Exotic seaweed alert at Adelaide's Port River

NSWCI-Environmental Report 2002

C. taxifolia was found in Adelaide's West Lakes in Australia. To reduce the spread of the alga, a fishing ban was implemented and flows into and out of the lake were minimized.

Freedenberg M

Proceedings of the *Caulerpa taxifolia* Scientific Review Panel. Cal Dept of Fish and Game, Habitat Conservation Planning Branch

Proceedings of the Caulerpa taxifolia Scientific Review Panel 2002, 26 pp

Cal Dept of Fish and Game, Habitat Conservation Planning Branch, US Fish and Wildlife Service-Aquatic Nuisance Species Task Force sponsored this review panel in San Diego, CA. The question of the review was "If a new *Caulerpa taxifolia* infestation occurs, is the eradication response being used in California suitable and does it have an appropriate probability of succeeding in the eradication of a new infestation?"

Web-based Articles

Thake B, Herfort L, Randone M, Hill G

Susceptibility of the Invasive Seaweed *Caulerpa taxifolia* to Ionic Aluminum

Botanica Marina 2003, 46

C. taxifolia susceptibility to aluminum chloride was evaluated. After exposure to 1 M aluminum chloride for less than 2 hrs, photosynthesis was completely and irreversibly inhibited. The native seagrass, *Posidonia oceanica*, was unaffected by the treatment.

Biocontrol

Journal

Andre J, Gyruis E, Lawler LR

Comparison of the diets of sympatric dugongs and green turtles on the Orman Reefs, Torres Strait, Australia

Wildlife Research 2005, 32:53-62

A study was conducted to investigate the feeding habits of dugongs and green turtles (*Chelonia mydas*) on the Orman Reefs situated between Australia and Papua New Guinea. It was determined that dugongs fed exclusively on seagrasses whereas the green turtles fed on seagrasses and algae. The primarily alga species fed on were the *Hypnea spp.*, *Laurencia spp.*, and *Caulerpa spp.* The *Caulerpa spp.* included *C. cupressoides* and *C. racemosa*.

Cavas L, Yurdakoc K, and Yokes B

Antioxidant status of *Lobiger serradifalci* and *Oxynoe olivacea* (Opisthobranchia, Mollusca)

Journal of Experimental Marine Biology and Ecology 2005, 314:227-235

Caulerpenyne is secreted by *Caulerpa spp*. as a defensive mechanism. *L. serradifalci* and O. *olivacea* are Mediterranean sea slugs that can feed on invasive *Caulerpa* species. It has been shown that caulerpenyne production increases with temperature suggesting that higher caulerpenyne levels may be associated with changes in the antioxidant nature of the sea slugs. The authors looked at the antioxidant status of *L. serradifalci* and *O. olivacea* by determining the levels of the antioxidant enzymes superoxide dismutase, catalase, glutathione peroxidase, lipid peroxidation, and oxidized glutathione at two different temperatures. It was determined that the superoxide dismutase, catalase and glutathione peroxidase increased with the higher temperature in both species. Lipid peroxidation decreased in both species. Oxidized glutathione increased in *O. olivacea* at the higher temperature, whereas, in *L. serradifalci* no changes were detected.

Davis AR, Benkendorff K, Ward and D

Responses of common SE Australian herbivores to three suspected invasive *Caulerpa*

Marine Biology 2005, 1461:859-868

Common the intertidal and shallow subtidal zone grazers, *Aplysia sydneyensis*, Turbo torquatus, and *Turbo undulatus*, were examined to determine if they can be used as biocontrol agents of *C. taxifolia*, *C. scalpelliformis*, and *C. filiformis*. Solvent extracts were prepared from these algae did not deter any of the glazers. In fact, *Turbo undulatus*, when offered fronds from *C. filiformis*, *Ulva spp.* and *Sargassum spp*., T. undulatus had the lowest preference for *C. filiformis*. Therefore, it was concluded that these herbivores are not biocontrol candidates for *Caulerpa*.

Marin A and Ros J

Chemical defenses in Sacoglossan Opisthobranchs: Taxonomic trends and evolutive implications

Scientia Marina 2004, 68(Suppl. 1):227-241

This paper summarizes kleptoplasty and chemical defenses in Sacoglossans sea slugs. Some members of this group, *Oxynoe* and *Elysia*, feed on *Caulerpa taxifolia*.

Verlaque M, Afonso-Carrillo J, and Gil-Rodriguez C

Blitzkrieg in a marine invasion: *Caulerpa racemosa var. cylindracea* (Bryopsidales, Chlorophyta) reaches the Canary Islands (NE Atlantic)

Biological Invasions 2004, 6:269-281

The present of *C. racemosa* was verified in the Canary Islands using genetic analysis comparing rDNA ITRS1, 5.8S, ITS2, and 18S rDNA intron sequences. The genetic analysis was supplemented with morphological studies.

Coquillard P, Thibaut T, Hill DRC, Gueugnot J, Mazel C, Coquillard Y

Simulation of the Mollusc Ascoglossa *Elysia subornata* Population Dynamics: Application to the Potential Biocontrol of *Caulerpa taxifolia* Growth in the

Ecological Modeling 2003, 135:1-15

A biocontrol simulation of sea slug *Elysia subornata* for the control of *C. taxifolia* was studied. Parameters observed included growth, survival, reproduction, feeding on *C. taxifolia*, and foraging of the slug. The results showed that *E. subornata* did not adapt well to the Mediterranean and that 4 adults per meter sq were required for good biocontrol of the plant.

Secord D

Biological control of marine invasive species: cautionary tales and land-based lessons

Biological Invasions 2003, 5:117-131

Several taxa of oligophagous sacoglossan sea slugs attack *Caulerpa taxifolia* either by kleptoplasty (consuming the chloroplasts) or by herbivory. *Oxynoe olivacea* and *Lobiger serradifalci* feed on *C. taxifolia*. However, the feeding rates are very low. *Elysia subornata* also feed on *Caulerpa*. However, simulation modeling suggested that the cold temperature of the Mediterranean Sea would be detrimental to the feeding habit of this sea slug. Though it was thought the sacoglossans had highly specific feeding preferences, recent experimental results suggest that "host shifts and host range expansions among native and introduced algal hosts by native sacoglossan slugs are frequent occurrences in historical time" (Trowbridge and Todd 2001).

Gianguzza P, Airoldi L, Chemello R, Todd CD, Riggio S

Feeding preferences of *Oxynoe olivacea* (Opisthobranchia: Sacoglossa) among three *Caulerpa* species

Journal of Molluscan Studies 2002, 68:289-290

The sea slug *O. olivacea* belongs to the order Oxynoacea whose feeding is restricted to the algae belonging to the *Caulerpa* genus. The feeding preferences of *O. olivacea* between the native *C. prolifera*, and two invasive species, *C. taxifolia*, and *C. racemosa* were studied. All studies showed that *O. olivacea* preferred *C. prolifera*.

Thibaut T, Meinesz A, Amade P, Charrier S, De Angelis K, Ierardi S, Mangialajo L, Melnick J, and Vidal V

Elysia subornata (Mollusca) a potential control agent of the alga *Caulerpa taxifolia* (Chlorophyta) in the Mediterranean Sea

Journal of the Marine Biological Association 2001, 81:497-504

The sea slug *Elysia subornata* was tested for its effectiveness in being a biocontrol agent for controlling *C. taxifolia*. *E. subornata* was able to reproduce and reached levels effective in controlling *C. taxifolia*. However, the cold winter temperatures of the Mediterranean was detrimental to the survival of the sea slug.

Zuljevic A, Thibaut T, Elloukal H, Meinesz A

Sea slug disperses the invasive *Caulerpa taxifolia*

Journal of the Marine Biological Association of the United Kingdom 2001, 81:343-

Experiments were conducted to determine if the sea slug, *Lobiger serradifalci*, would be a good candidate as a biocontrol agent for the control of *C. taxifolia*. Results showed that instead of controlling *C. taxifolia, L. serradifalci* cut the fronds into tiny little fragments that were capable of regenerating into whole plants. *L. serradifalci*, instead of controlling the alga, was spreading it.

Thibaut T and Meinesz A

Are the Mediterranean ascoglossan molluscs *Oxynoe olivacea* and *Lobiger serradifalci* suitable agents for a biological control against the invading tropical alga *Caulerpa*

C.R. Academie des Sciences, Paris 2000, 323:477-488

The sea slugs, *O. olivacea* and *L. serradifalci* , were studied to determine their effectiveness in controlling *C. taxifolia* in the Mediterranean. These organisms were rarely found on *C. taxifolia* but were chosen because they were found feeding on the alga. The rates of feeding were temperature dependent with the rates 2 to 3 times slower at temperatures between 13 and 16^{o}C versus at 22^{o}*C.* Even at the higher temperature, the sea slugs only fed and killed approximate 5 cm of fronds very 3 to 7 days.

Cimino G and Ghiselin MT

Chemical defense and evolution in the Sacoglossa (Mollusca: Gastropoda: Opisthobranchia)

Chemoecology 1998, 8:51-60

It is believed that the Sacoglossa evolved in close association with the genus *Caulerpa*. Theories are now being presented that suggest that another green alga was the original host. Both *Oxynoe olivacea* and *Lobiger serradifalci* feed on *Caulerpa prolifera*. *C. prolifera* produces caulerpenyne. Both sacoglossan converts the toxic caulerpenyne to oxytoxin-1 and oxytoxin-2. *O. olivacea* when attack, exudes oxytoxin-2.

Paul VJ and Hay ME

Seaweed susceptibility to herbivory: chemical and morphological correlates

Marine Ecology Progress Series 1986, 33:255-264

The resistance of 82 species of seaweeds to herbivory including several *Caulerpa spp.* (C. *racemosa*, *C. prolifera*, and *C. cupressoides*) was investigated. Secondary metabolites were produced by 71% of the species least susceptible to herbivory; while only 25% of the species most susceptible to herbivory produced secondary metabolites. The *Caulerpa* spp. investigated fell into the first category.

Meetings Abstracts/Symposium Proceedings

Anderson LWJ

Biological control of killer algae, *Caulerpa taxifolia*

California Conference on Biological Control Proceedings, UC Davis 2002, 79

To control *C. taxifolia*, biocontrol agents are being examined. 4 species of sea slugs (*Oxynoe azuropunctata*, *Elysia subornata*, *Oxynoe olivacea* and *Lobiger serradifalci*) have been used as agents. However, none has been effective. For example, *L. serradifalci*, when it feeds on *C. taxifolia* creates fragments which then produce more plants. *E. subornata* is tropical and cannot survive cold the temperatures of the Mediterranean. Despite these set backs, the search for biocontrol agents continues.

Web-based Articles

Kohler E

"Re: *Lobiger serradifalci* from the Mediterranean"

Sea Slug Forum 2003

Lobiger serradifalci naturally feeds on *Caulerpa prolifera*. Though it also feeds on *Caulerpa taxifolia*, it may be spreading the alga rather than controlling it. When *L. serradifalci* feeds, it pierces holes in the cell walls, resulting in weaken fronds, which then break off. These small pieces that give rise to entire plants.

Reproduction/Dispersal

Journal

Adolph S, Jung V, Rattke J, and Pohnert G

Wound closure in the invasive green alga *Caulerpa taxifolia* by enzymatic activation of a protein cross-linker

Angewandte Chemie 2005, 44:2806-2808

Caulerpa taxifolia initially forms a gelatinous external wound plug (EWP) in response to a mechanical injury. The EWP prevents the cytoplasm from seeping out of the unicellular alga. After the deposition of the EWP, an insoluble material is then deposited internal to the EWP to form an internal barrier. The resulting fragment is genetically identical to the parent fragment and is fully viable. Experimental results suggests that the internal barrier may be formed of cross linking proteins involving caulerpenyne reaction with esterases to form oxytoxin 2. Oxytoxin-2 a protein-crosslinking reagent.

Glasby TM, Gibson PT, and Kay S

Tolerance of the invasive marine alga *Caulerpa taxifolia* to burial by sediment

Aquatic Botany 2005, 82:71-81

Populations of *Caulerpa taxifolia* were subjected to different degree of coverage with sediment. One population was completely covered with sediment at a depth of 5 cm. A second population was only partially covered allowing exposure of some fronds. The third population consisted of the control alga grown under optimal conditions. The results showed that the total length of stolons for the control and the partially covered populations were similar. In contrast, the completely covered population had total lengths approximately 9 times lower than the first two populations. Surprisingly, even after 17 days of complete burial, 35% of the covered *Caulerpa* survived suggesting that complete control of *Caulerpa* must involve penetration of the substrate.

Tsirika A and Haritonidis S

A survey of the benthic flora in the National Marine Park of Zakynthos

Botanical Marina 2005, 48:38-51

From April 2001 to February 2003, 182 taxa of microalgae were found in the benthic marine macroflora in Laganas Bay. The hard rocky substrata had mainly *Cystoseira* while the soft bottom consisted mostly of *Posidonia* oceania. *Caulerpa racemosa* was found on both types of substrate.

Wright JT

Differences between native and invasive *Caulerpa taxifolia*: a link between asexual fragmentation and abundance in invasive populations

Marine Biology 2005, 147:559-569

Populations of native *Caulerpa taxifolia* from subtropical Moreton Bay, Australia and the invasive type from temperate southeastern Australia were compared. Traits required for successful introduction such as thallus size and density, fragmentation, and total biomass were examined. It was determined that the native *C. taxifolia* had larger stolons and fronds than the invasive type. However, the invasive type had higher densities of stolons, fronds, and fragmented fronds. Invasive *C. taxifolia* had up to 45% of it's stolons originating from fragmented fronds; whereas, only 12% of the native type stolons orginated from fragmented fronds. In addition, the invasive *C. taxifolia* biomass was also greater.

Curiel D, Rismondo A, Bellemo G, and Marzocchi M

Macroalgal biomass and species variations in the Lagoon of Venice (Northern Adriatic Sea, Italy): 1981-1998

Scientia Marina 2004, 68(1):57-67

Due to increased industrialization, the floral in the Lagoon of Venice has changed considerably. The macroalgae populations, including *Ulva rigida, Enteromorpha spp., Cladophora spp.*, and *Chaetomorpha spp.*, have increased while the native sea grasses decreased. In this study, using in situ measurements and aerial photo surveys, it was determined that the macroalgae populations peaked in 1989-1990. In the 1990's, the sea grasses population increased while that of the macroalgae decreased. It was hypothesized that during this period, the water of the lagoon was usually cold, thus inhibiting the rapid growth of the macroalgae.

Millar AJK

New records of marine benthic algae from New South Wales, eastern Australia

Phycological Research 2004, 52:117-128

This paper list 24 species of marine macroalgae recorded for the first time at New South Wales, Australia. One species is the invasive cold-water tolerant *Caulerpa taxifolia*. Previously, this species was identified as the native, non-invasive alga from Lord Howe Island.

Padilla DK and Williams SL

Beyond ballast water: aquarium and ornamental trades as sources of invasive species in aquatic ecosystems

Frontiers in Ecology and the Environment 2004, 2(3):131-138

One-third of the aquatic invasive species were imported as aquarium or ornamental species. These include *Caulerpa taxifolia* and *Eichhornia crassipes*. At the present regulation of the aquarium trade has not been effective to prevent the spread of invasive species.

Simberloff D and Gibbons L

Now you see them, now you don't!--population crashes of established introduced species

Biological Invasions

Nonindigenous species at times exhibit a phenomenon known as population crash. By studying 17 introduced species, the authors hypothesized 4 probably causes for the crashes. These are competition with other introduced species; exhaustion of resources; parasitism by subsequently introduced species; and adaptation by native herbivore.

Jaubert JM, Chisholm JRM, Minghelli-Roman A, Marchioretti M, Morrow JH, and Ripley HT

Re-evaluation of the extent of *Caulerpa taxifolia* development in the northern Mediterranean using airborne spectrographic sensing

Marine Ecology Progress Series 2003, 263:75-82

44% of the total area of *C. taxifolia* on the south coast of France was resurveyed with airborne multispectral imaging and validated with underwater survey. The results showed the previous estimation of the density of *C. taxifolia* was 10 fold too high. Also, the alga had not supplanted the native *Posidonia oceanica*.

Komatsu T, Ishikawa T, Yamaguchi N, Hori Y, and Ohba H

But next time?: unsuccessful establishment of the Mediterranean stain of the green seaweed *Caulerpa taxifolia* in the Sea of Japan

Biological Invasions 2003, 5:275-277

63 public aquaria were surveyed in Japan for possessing *C. taxifolia* as cultures or displayed in exhibits. 16 responded positively. All aquaria received or purchased their specimens from other aquaria. The Notojima aquarium released into the Sea of Japan *C. taxifolia* from a 1 cubic meter cage. These were only able to produce 2 colonies of the alga less than 2 m in diameter even after two years. It was speculated that the temperatures of waters of the Sea of Japan in the winter were lethal for the alga.

Collado-Vides L

Clonal architecture in macroalgae: ecological and evolutionary perspectives

Evolutionary Ecology 2002, 15:531-545

This paper reviews the ecological and evolutionary consequences of clonal growth in marine microalgae. Subject areas reviewed included modular construction, life cycle and ecological consequences.

Hill C, Thibaut T, and Coquillard P

Predicting invasive species expansion using GIS & simulation coupling

Modeling & Simulation Magazine 2002, 1(1):30-35

This describes a model using GIS and discrete event simulation coupling to predict the spread of *C. taxifolia*. The model developed interacted with maps created with GIS.

Phillips JA, Price IR

How different is Mediterranean *Caulerpa taxifolia* (*Caulerpa*les: Chlorophyta) to other populations of the species?

Marine Ecology Progress Series 2002, 238:61-71

Authors studied Australian and European herbaria samples, recent field collections and observations by other researchers to try to determine if *C. taxifolia* is indigenous to Australia. They concluded that *C. taxifolia* is indigenous to tropical/subtropical Australia since it has been documented to occur in those regions 80 to 145 years ago. A recent discovery of a population in New South Wales has not been documented in the literature and therefore its origin is not known. The authors suggest that molecular genetics may aid in identifying the origin of this population.

Renoncourt L and Meinesa A

Formation of propagules on an invasive strain of *Caulerpa racemosa* (Chlorophyta) in the Mediterranean Sea

Phycologia 2002, 41(5):533-535

C. racemosa is reported to produce vegetative propagules called ramuli on the fronds. The ramuli detach from the fronds and can sprout to give rise to a plant. The production of ramuli, however, is extremely low.

Silva Paul C, Woodfield RA, Cohen AN, Harris LH, and Goddard JHR

First report of the Asian kelp *Undaria pinnatifida* in the northeastern Pacific Ocean

Biological Invasions 2002, 4:333-338

U. *pinnatifida* was first discovered in California in 2000. In 2001, it was found from Los Angeles to Long Beach, Catalina Island and north to Monterey Harbor. Its means of dispersal included cultivation, accidental transport with oysters, and attaching to vessel hulls.

Williams SL and Grosholz ED

Preliminary reports from the *Caulerpa taxifolia* invasion in southern California

Marine Ecology Progress Series 2002, 233:207-310

This is the first report of *C. taxifolia* sighting in Huntington Harbor, Ca. It was capable of growing in cold temperatures and the size of the fronds, density and biomass were similar to the strain in the Mediterranean.

Ceccherelli G and Piazzi L

Dispersal of *Caulerpa racemosa* fragments in the Mediterranean: Lack of detachment time effect on establishment

Botanica Marina 2001, 44:209-213

Dispersal of *C. racemosa* by fragmentation was temporally dependent. It spread in greater numbers in the summer months. This is similar to the pattern exhibited by *C. taxifolia*.

Jousson O, Pawlowski J, Zaninetti I, Zechman FW, Dini F, Di Guiseppe G, Woodfield R, Millar A, Meinesz A

Invasive alga reaches California

Nature 2000, 408:157

The strain of *C. taxifolia* that was found in southern California is that same strain that was found in the Mediterranean. It was found from Carlsbad to Huntington Harbour, CA. It covered 3,500 sq m in Carlsbad and 20,000 sq m in Huntington Harbor. PCR was used to compare the ITS rDNA from 12 California specimens of *C. taxifolia* to those from the Mediterranean. 11 were found to match.

Ceccherelli G and Cinelli F

The role of vegetative fragmentation in dispersal of the invasive alga *Caulerpa taxifolia* in the Mediterranean

Marine Ecology Progress Series 1999, 182:299-303

C. taxifolia can reproduce by fragmentation. The success of these fragments to grow into whole plants were temporally and spatially dependent. The largest percentage of establishment occurred during the summer months at shallow sites, followed by the spring and then the lowest levels in the winter months.

Magazine

Gluick A

The Alien Invasion

Dive Training 2002, 12(6):112-117

This article is an informative piece intended for recreational divers who might encounter invasive plants including *C. taxifolia* and gives recommendations to prevent and control invasive species. This includes cleaning boat motors of any alien plant species.

Meetings Abstracts/Symposium Proceedings

Jaubert J, Minghelli A, Chisholm JR, Marchioretti M, Morrow J, Ripley H

Cartography and Risk Assessment of the Development of the Alga *Caulerpa Taxifolia* in the Northwest Mediterranean

Geographical Information Systems International Group-Third International Conference on Marine Bioinvasions

Using airborne multispectral imaging and underwater survey, 44% of the *C. taxifolia* down to a depth of 20 m on the south coast of France was mapped. Airborne surveys were conducted using a compact airborne spectrographic imager (casi). Underwater surveys were done by drivers. GPS was used to localize the positions of each population. Maps were then prepared localizing populations of *C. taxifolia*. They were found in partially vacant stressed environments. The authors concluded that *C. taxifolia* risk to most endemic species "to be considerably lower then formerly predicted."

Collado-Vides L

Morphological Plasticity and Invasive Potential of Some *Caulerpa* Species

International Caulerpa taxifolia Conference Proceedings 2002

The invasiveness of *C. taxifolia* is characterized by several traits: 1. high growth rate 2. ability to take up nutrients from sediments 3. ability to tolerate low temperatures 4. lack of predators 5. asexual reproduction. Other species of *Caulerpa* display similar traits, thus may be potential problems. Different species of *Caulerpa* displayed different growth forms. More compact types colonized reef habitats while more open forms were found in lagoons. Only *C. cupressoides* was found in both habitats.

Collado-Vides L and Ruesink J

Morphological plasticity and invasive potential of some *Caulerpa* species

International Caulerpa taxifolia Conference Proceedings 2002

Traits associated with plant invasiveness are high growth rate, nutrient uptake from sediments, tolerance to low water temperatures, fragmentation, continual production of modules, and opportunistic growth. All these traits are exhibited by *Caulerpa taxifolia*. Other *Caulerpa* species, such as *C. cupressoides* exhibit similar traits suggesting that other members of the genus are potential problems.

Frisch F and Murray S

The Availability of *Caulerpa spp.* And “Live Rock” in Retail Aquarium Outlets in Southern California

International Caulerpa taxifolia Conference Proceedings 2002

A survey was conducted of 50 retail saltwater aquarium stores in southern California. The results of the survey showed that 52% of the stores sold some form of *Caulerpa spp.* 10% sold *C. taxifolia*, 18% sold *C. seriate*, 14% sold *C. racemosa*, and 14% sold *C. racemosa var. lamoruouxii*.

Frisch SM and Murray SN

The diversity and availability of *Caulerpa* species found in retail aquarium outlets in southern California, USA

16th Northwest Algal Symposium Abstracts 2002

A survey was conducted of 50 retail saltwater aquarium stores in southern California. The results of the survey showed that 52% of the stores sold some form of *Caulerpa spp.* 10% sold *C. taxifolia*, 18% sold *C. seriate*, 14% sold *C. racemosa*, and 14% sold *C. racemosa var. lamoruouxii*.

Frisch SM, Murray SN

The diversity and availability of *Caulerpa* species found in retail aquarium outlets in southern California, USA

Botany 2002: Botany in the curriculum: Integrating research and teaching 2002

Authors surveyed 50 aquarium stores in southern California and discovered 16 *Caulerpa* species in these businesses. 52% of the stores sold some form of *Caulerpa*. *C. taxifolia* was found in 10% of the stores, *C. serrulata var. hummii* in 18%, *C. racemosa* in 14%, and *C. racemosa var. lamoruouxii* in 14% of the stores.

Meinesz A

Summary of Mediterranean Invasion and Management

International Caulerpa taxifolia Conference Proceedings 2002

At the end of 2000, 103 colonies of *C. taxifolia* covered 131 square kilometers of the Mediterranean coastline of Spain, France, Monaco, Italy, Croatia, and Tunisia . By the summer of 2001, 30 additional colonies were discovered in France.

Meinesz A

Introduction for the International *Caulerpa taxifolia* Conference

International Caulerpa taxifolia Conference Proceedings 2002

Since *C. taxifolia* introduction into the Mediterranean in 1984, it is now found in California, Japan and Australia. After 10 years of studies, it is believed that this invading strain is originally from Moreton Bay, Australia. Two characteristics of this alga which make it difficult to control is its ability to grow in many climates and lack of predators.

Millar A and Talbot B

The Introduction of *Caulerpa taxifolia* in New South Wales, Australia

International Caulerpa taxifolia Conference Proceedings 2002

C. taxifolia was first reported in Port Hackling in Sydney Harbor in 2000. It has now been sighted in Lake Conjola, Careel Bay, Lake Macquarie, and Lake Burrill. Genetic studies suggest that these infestations came from two introductions. The New South Wales government has designated *C. taxifolia* as a noxious species. Eradication has been difficult. However, some success using divers to manually remove the alga was noted. The alga, however, grew back in 6 months. Also the use of rock salt was effective in killing *C. taxifolia* but its affect on the rhizoids have yet been determined.

Silva P

Overview of the Genus *Caulerpa*

International Caulerpa taxifolia Conference Proceedings 2002

75 species of *Caulerpa* have been identified. All inhabit warm water. Some species exhibit a high degree of polymorphism while others show very little variation. All can reproduction asexually by fragmentation. Sexual reproduction is uncommon but when it does occur, biflagellate gametes are produced.

Trowbridge CD

Invasion Ecology of *Codium fragile spp.. tomentosoides*: Implications for *Caulerpa taxifolia* Incursions

International Caulerpa taxifolia Conference Proceedings 2002

The green alga *Codium fragile*, both native and introduced, have many similarities to *C. taxifolia*. Both are coenocytic and have robust chloroplasts and are fed on by sacoglossan sea slugs. Both can reproduce by thallus fragmentation. Studying *C. fragile* could provide information on how to effectively control *C. taxifolia*.

Zuljevic A and Antolic B

Reproduction of *Caulerpa taxifolia* in the Mediterranean Sea

International Caulerpa taxifolia Conference Proceedings 2002

C. taxifolia can regenerate from thallus fragments, stolon fragments and rhizoids. Very small fragments of thallus will give rise to a whole plant. In tropical regions, *C. taxifolia* can reproduce sexually. The alga is monoecious and a fertile plant is distinguish by appearance of reticulate depigmentation and development of papillae mostly on the frond axes. In the Mediterranean, *C. taxifolia* only produces male gametes and thus sexual reproduction does not occur. It is not known why female gametes are absent.

Newspaper/Magazine

The Mediterranean invaded by a new tropical alga

Le Monde. Fr 2004

Caulerpa racemosa was reported to have invaded the Mediterranean. Both *C. taxifolia* and *C. racemosa* were found in this body of water. *C. taxifolia* covered 17,000 hectares and 300 km of coastline.

Technical Report

Biodiversity

New South Wales State of the Environmental 2003

This report summarizes the introduced aquatic species in the waters of New South Wales including *Caulerpa taxifolia* that was first reported in NSW in April 2000. *C. taxifolia* negatively impacts any environment that it is introduced into. It quickly shades out native plants by its rapid growth. The NSW government has declared this alga as a "Noxious Marine Vegetation" and committed 1 million dollars for aquatic pest and weed management with the bulk going towards *C. taxifolia* control. The NSW Fisheries mapped infested areas, restricted commercial fishing in these areas, and began an outreach program to educate the public.

Anderson LWJ, Holmberg D, Tan W, O'Callaghan A, and Gee D

Assessment of *Caulerpa taxifolia* viability in sediment from Agua Hedionda eradication treatments

CDFG Final Report 2003

Core samples from sediments treated with chlorine to eradicate *C. taxifolia* were evaluated for regrowth of *C. taxifolia* from rhizoids still incorporated in the core samples. The results showed that there were no regrowth from any of the treated core samples. However when explants of *C. taxifolia* were planted into control cores (weren't treated with chlorine), they grew well.

Mack RN, Barrett SCH, Defur PL, MacDonald WL, Madden LV, Marshall DS, McCullough DG, Mcevoy PB, Nyrop JP, Reichard SH, Rice KJ, and Tolin SA

Predicating Invasions of Nonindigenous Plants and Plant Pests

National Research Council 2002

A report by the Committee on the Scientific Basis for Predicating the Invasive Potential of Plants and Pests drawn up for APHIS's concern about the ability to predict the outcome of an introduction of a nonindigenous species. 4 conclusions were drawn. The record of a plant's invasiveness is the most reliable predictor. At present there are no scientific principles capable of identifying the potential of an invading species. Therefore, observations and experiments must be conducted to evaluate the impact of these invading species in their new environment. Finally, all information about the invading species must be organized into databases for easy access.

Web-based Articles

Teruhisa K, Tomoji I, Nobuyuki Y, Yukiki H, and Hideo O

But next time?: Unsuccessful Establishment of the Mediterranean Strain of the Green Seaweed *Caulerpa taxifolia* in the Sea of Japan

National Institute of Informatics (NII-REO) Klumer Online 2003, 5(3)

A survey was conducted of the 63 public aquariums in Japan and determined that 16 of them cultured or exhibited *C. taxifolia*. The Notojima aquarium released the plant into the Sea of Japan in a cage. Only 2 colonies less than 2 meters in diameter were form. This strain was (determined by ITS rDNA analysis) the same as the aquarium-Mediterranean and California strain. The authors suggested that the water was too cold for the *C. taxifolia* to *proliferat*e at this location.

Millar A, Grey D, and Shaffelke B

Caulerpa taxifolia - First report of its introduction to eastern Australia

Sea Slug Forum 2002

An invasive strain of *C. taxifolia* that is cold-water tolerant was first discovered in New South Wales, Australia in 2002. It is believed to have been established 5 to 15 years ago. 3 populations at 2 sites covering 1 and 10 hectares have been identified. A *C. taxifolia* management team comprising of NSW Fisheries, the Sydney Botanic Gardens and the Centre for Research on Introduced Marine Pests in Tasmania was set up to study and control this menace.

Competition/Interactions with other Plants

Book

Dumay O and Pergent G

Strategies of interaction between indigenous Magnoliophyte *Posidonia oceanica* and invasive Bryopsydophycees *Caulerpa racemosa* and *Caulerpa taxifolia*

Congrès International Identité et Environment en Méditerranée 2002

The interactions between the native *P. oceanica* and the invasive *C. taxifolia* and *C. racemosa* were studied. Frond lengths and leaf area index of *P. oceanica* decreased while the production of caulerpenyne increased with increased interaction with both *Caulerpa* spp. In contrast, the frond lengths of the *Caulerpa spp.* increased and the caulerpenyne levels decreased with increased interaction with *P. oceanica*.

Journal

Dumay O, Costa J, Desjobert JM, and Pergent G

Variations in the concentration of phenolic compounds in the seagrass *Posidonia oceanica* under conditions of competition

Phytochemistry 2004, 65:3211-3220

The native *Posidonia oceanica* in the Mediterranean altered its production of phenolics in response to the degree of interaction with *Caulerpa taxifolia* but not with *Caulerpa racemosa*. This response was both seasonal and temporal. In adult leaves, the levels of phenolics were higher in November and lower in September and March. The levels in intermediate leaves and sheaths were unchanging.

Ara J, Sultana V, Ehteshamu-Haque S, Athar M, Qasim R

Antibacterial activity of marine macro-algae from Karachi coast

Bulletin of the Polish Academy of Sciences Biological Sciences 2002, 50(4):199-206

Ethanolic extracts from 22 marine algae including *C. taxifolia* were tested for antimicrobial activities against 6 bacterial species (Staphylococcus *aureus*, *Bacillus subtillis*, *Salmonella typhimurium*, Escherichia *coli*, *Pseudomonas aeruginosa* and *Agrobacterium tumefaciens*. *C. taxifolia* inhibited growth of all bacterial species expect for *P. aeruginosa*. The various extraction fractions also exhibited inhibitory abilities. The hexane and chloroform fractions inhibited *S. aureus*, *S. typhimurium*, and *E. coli*. The methanol fraction inhibited *B. subtillis*, *S. typhimurium* and A. *tumefaciens*.

Ceccherelli G and Cinelli F

Habitat effect on spatio-temporal variability in size and density of the introduced alga *Caulerpa taxifolia*

Marine Ecology Progress Series 2002, 474(1-3):57-66

In the Mediterranean, *C. taxifolia* occupied 3 distinct habitats: 1) edge of *Posidonia oceanica*, 2) within *Cymodocea nodosa* beds and 3) on sand and cobble stones. The longest fronds on *C. taxifolia* were found at the edge of the *P. oceanica* bed. They were intermediate lengths in the *C. nodosa* beds and shortest on sand and cobble stones. The size of the fronds decreased in the spring in *C. nodosa* beds and sand but not in *P. oceanica* .

Ceccherelli G and Sechi N

Nutrient availability in the sediment and the reciprocal effects between the native seagrass *Cymodocea nodosa* and the introduced rhizophytic alga *Caulerpa taxifolia*

Hydrobiologia 2002, 474(1-3):57-66

Plot containing *C. taxifolia* and the seagrass *C. nodosa* were used as experimental sites. Experimental treatments included control conditions, addition of nutrients (N and P) and manual removal of either *C. nodosa* or *C. taxifolia* from the sites. Uptake of P did not appear to be enhanced by the addition of the external source by either species. However, when N was added, *C. taxifolia* actively took up the excess whereas *C. nodosa* did not. *C. nodosa* shoot density was not affected by either nutrient regimes or the presence or absence of *C. taxifolia*. When *C. taxifolia* was grown in the presence of *C. nodosa* , the blades were larger than the absence of *C. nodosa* than without nutrient enrichment. The density of *C. taxifolia*, however, did not appear to be influenced by *C. nodosa* or nutrient enhancement.

Ceccherelli G, Piazzi L, and Cinelli F

Response of the non-indigenous *Caulerpa racemosa* (Forsskal) J Agardh to the native seagrass

Journal of Experimental Marine Biology and Ecology 2000, 243:227-240

The spread of *C. racemosa* into beds of the native sea grass *Posidonia oceanica* is dependent upon the density of the sea grass. At the edge, the lengths of the *C. racemosa* were longest in the mats with the lowest density of *P. oceanica*. The spread of the *C. racemosa* into a bed of established *P. oceanica* was greatest in the lowest density of *P. oceanica*.

Dumay O, Fernandez C, and Pergent G

Primary production and vegetative cycle in *Posidonia oceanica* when in competition with the green algae *Caulerpa taxifolia* and *Caulerpa racemosa*

Journal of Marine Biological Association of the United Kingdom 2002, 80:379-387

Posidonia oceanica is one of the primary species inhabiting the Mediterranean and is used extensively as a bio-indicator of stress. In competition with *C. taxifolia* and *C. racemosa*, *P. oceanica* leaf lengths, leaf index and mean age of the leaves decreased. However, the percentage of leaves without apices, epiphyte biomass, mean number of leaves per shoot increased. *Caulerpa* did not affect the below-ground tissue production.

Dumay O, Pergent G, Pergent-Martini C, Amade P

Variations in Caulerpenyne Contents In *Caulerpa taxifolia* and *Caulerpa racemosa*

Journal of Chemical Ecology 2002, 28:343-352

Caulerpenyne was measured in *C. taxifolia* and *C. racemosa* as function of season and level of competition with *Posidonia*. In all occasions, caulerpenyne levels were always highest in *C. taxifolia*. For all species, the highest levels of caulerpenyne occurred in the autumn (Sept/Nov) and lowest levels in the spring (Apr/May). With increasing competition, the caulerpenyne levels decreased in *Caulerpa* while frond lengths increased.

Piazzi L and Ceccherelli G

Effects of competition between two introduced *Caulerpa*

Marine Ecology Progress Series 2002, 225:189-195

Competition between the invasive species *C. taxifolia* and *C. racemosa* was studied. Stolon lengths of both species exhibited temporal patterns similar to those found by earlier studies. When *C. taxifolia* fragments were transplanted into beds of *C. racemosa*, C. *taxifolia* stolon lengths decreased. *C. taxifolia* fronds were chlorotic and degraded. However, when *C. taxifolia* fragments were transplanted into beds of *C. taxifolia*, bed density increased. Authors hypothesized that if both *C. taxifolia* and *C. racemosa* invaded the same region, *C. racemosa* would out compete *C. taxifolia*.

Piazza L, Ceccherelli G, and Cinelli F

Threat to macroalgal diversity: effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean

Marine Ecology Progress Series 2001, 210:149-159

Introduction of *C. racemosa* into the benthic macroalgal community in northwestern Mediterranean completely altered the community. Within 6 months of the introduction, *C. racemosa* completely covered the substratum of the area and outgrew the native macroalgal species thus reducing the species diversity in the area. When the *C. racemosa* density was reduced from December to May, the native macroalgal did not return to conditions prior to the introduction of *C. racemosa*.

Ceccherelli G, Cinelli F

Effects of *Posidonia oceanica* canopy on *Caulerpa taxifolia* size in north-western Mediterranean bay

Journal of Experimental Marine Biology and Ecology 1999, 240:19-36

C. taxifolia was transplanted into various densities of *P. oceanica* (10%, 50%, and 100% of natural density) and at 2 or 20 m depth. Under all experimental conditions, the *C. taxifolia* was able to get established. The fronds of the alga were larger at the 10 m than at 2 m depth. Also the frond lengths exhibited seasonal fluctuations. They were longer in July (17.5 cm) than in March (4.5 cm) and also longer in the 10% density plot of *P. oceanica* than at the 50% or 100% plots.

Ceccherelli G, Piazzi L, Cinelli F

Short-term effects of nutrient enrichment of the sediment and interactions between the seagrass *Cymodocea nodosa* and the introduced green alga *Caulerpa taxifolia* in a Mediterranean bay

Journal of Experimental Marine Biology and Ecology 1997, 217:165-177

Plots containing *C. taxifolia* and the seagrass *C. nodosa* were used as experimental sites for 4 months. Experimental conditions included addition of nutrients (N and P) and manual removal of either *C. nodosa* or *C. taxifolia* from the sites. In the presence of *C. taxifolia* and under all nutrient conditions, the shoot density of *C. nodosa* was reduced by 45%. In contrast, *C. nodosa* did not have any affects on the growth of *C. taxifolia*. Nutrient additions apparently did not influence the growth of *C. nodosa*. However, in the presence of the nutrient enrichment, the density of *C. taxifolia* increased by 18.5%

Meetings Abstracts/Symposium Proceedings

Pergent G, Dumay O, Pergent-Martini C

Effects of the invasive interaction between *Posidonia oceanica* and two *Caulerpa* species

Integrated coastal and ocean resource management and development. MEDCOAST, Ravenne (Italy), 7-11 October 2003

The interactions between endemic *Posidonia oceanica*, *C. taxifolia*, and *C. racemosa* were compared at the French Riviera. With increasing interaction with the two *Caulerpa* species, *P. oceanica* leaf length and leaf are index were reduced. The number of leaves increased by 83% in *C. taxifolia* and by 27% in *C. racemosa*. In both species of *Caulerpa*, the fronds also increased in lengths. The number of tannin cells also increased while the secondary metabolites were reduced.

Ceccherelli G

The Spread of *Caulerpa taxifolia* in the Mediterranean: Dispersal Strategy, Interactions With Native Species, and Competitive Ability

International Caulerpa taxifolia Conference Proceedings 2002

C. taxifolia spreads by the asexual fragmentation of the thallus. In competition with *P. oceanica*, a large majority of the fragments can anchor at the edge of the seagrass bed. The alga most favorable growth environments are tuft habitats. In direct competition with *C. racemosa*, *C. taxifolia*, growth is higher as shown by stolon cover and blade density.

Pergent G, Dumay O, and Pergent Martini C

Interspecific competition between the Mediterranean seagrass *Posidonia oceanica* and the Bryopsidophyceae *Caulerpa taxifolia*

International Fifth Seagrass Biology Workshop Abstracts 2002

The interaction between endemic *Posidonia oceanica*, *C. taxifolia*, and *C. racemosa* was compared at the French Riviera. With increasing interaction with the two *Caulerpa* species, *P. oceanica* leaf length and leaf are index were reduced. The number of leaves increased by 83% in *C. taxifolia* and by 27% in *C. racemosa*. In both species of *Caulerpa*, the fronds also increased in lengths. The number of tannin cells also increased while the secondary metabolites were reduced.

Ceccherelli G and Sechi N

The effect of the two invasive tropical algae *Caulerpa taxifolia* and *Caulerpa racemosa* on the native seagrass *Cymodocea nodosa* in the Mediterranean

5th International Conference Ecology of Invasive Alien Plants 1999

A study was conducted to determine the effects of *C. taxifolia* and *C. racemosa* on the growth of the native seagrass, *C. nodosa*. Both algae reduced the shoot density of *C. nodosa*. However, the number of male and female flowers increased significantly in the present of the algae.

Web-based Articles

Montero JM

The Mediterranean ecosystems, threatened by the climatic change and the exotic species

Eco2site 2003

When one speaks of the invasion of the Mediterranean, one always mentions *C. taxifolia*. It grows very fast and at times can triple in mass. *C. taxifolia* produces at least 6 toxins including caulerpenyne. The amount of toxin produced is greater than that produced in its native environment. The toxins render the alga inedible to animals.

Caulerpenyne

Journal

Cutignano A, Notti V, d'Ippolito G, Coll AD, Cimino G, and Fontana A

Lipase-mediated production of defensive toxins in the marine mollusc *Oxynoe olivacea*

Organic and Biomolecular Chemistry 2004, 2:3167-3177

The sea slug, *O. olivacea*, can feed on *Caulerpa prolifera* and *Caulerpa taxifolia* even though these alga produce high levels of the toxin caulerpenyne. Caulerpenyne, however, cannot be detected in *O. olivacea*. To determine the fate of caulerpenyne, the authors prepared cell-free extracts from the sea slug and isolated caulerpenyne from *C. prolifera*. They demonstrated that the cell-free extracts contain a specific lipase that is capable of metabolizing caulerpenyne to give oxytoxin-1 and oxytoxin-2.

Pohnert G and Jung V

Intracellular compartmentation in the biosynthesis of caulerpenyne: Study on intact macroalgae using stable-isotope-labeled precursors

Organic Letters 2003, 5(26):5091-5093

Using radiolabelled 13C-acetate and $13CO_2$, it was shown that the sesquiterpene backbone of caulerpenyne was synthesized in the chloroplast and followed the methyl-erythritol-4-phosphate pathway. The addition of the caulerpenyne residues occurred in the cytosol.

Jung V, Thibaut T, Meinesz A, and Pohnert G

Comparison of the wound-activated transformation of caulerpenyne by invasive and noninvasive *Caulerpa* species of the Mediterranean

Journal of Chemical Ecology 2002, 28(10):2091-2105

The sesquiterpene caulerpenyne is the major secondary metabolic of *C. taxifolia*. It produces 6 mg caulerpenyne per gram fresh weight. Within one minute after wounding the caulerpenyne level was reduced by 50%. The caulerpenyne was converted to reactive aldehydes intermediates (7) and finally to the end product, oxytoxin 1. The roles of these reactive aldehydes have not been elucidated.

Jung V and Pohnert G

Rapid wound-activated transformation of the green algal defensive metabolite

Tetrahedron 2001, 57:7169-7172

Within minutes of after wounding, the three acetate groups of *C. taxifolia* caulerpenyne were cleaved yielding 1,4-bis-enol acetate moieties which then though tautomerisation resulted in the labile 1,4-dialdehydes. These metabolites may be involved with the defense mechanism of *C. taxifolia*.

Amade P and Lemee

Chemical defense of the Mediterranean alga *Caulerpa taxifolia*: variations in caulerpenyne production

Aquatic Toxicology 1998, 43:287-300

An HPLC method was developed to quantify the levels of caulerpenyne in *Caulerpa taxifolia*. Results indicated that caulerpenyne concentrations were temperature dependent. The highest levels were measured during the summer seasons when the temperature of the water was greater than 19^{o}*C.* In addition, the highest levels of caulerpenyne occurred in plants growing at depths of 5 to 20 meters.

Lemee R, Pesando D, Durand-Clement M, Dubreuil A, Meinesz A, Gurriero A, and Pietra F

Preliminary survey of toxicity of the green alga *Caulerpa taxifolia* introduced into the Mediterranean

Journal of Applied Phycology 1993, 5:485-493

The toxicity of caulerpenyne and crude plant extracts from *Caulerpa taxifolia* was tested. Three systems were used for testing: mice; mammalian cells and sea urchin eggs. Aqueous plant extracts were toxic to the mammalian cells and to mice. Methanolic plant extracts were toxic to all three systems. There was a seasonal fluctuation in the levels of toxicity. The aqueous extracts were more toxic from December to June than from July to November. The methanolic extracts were more toxic from July to November than from December to June. Seven terpenes were purified and the most active was caulerpenyne.

Paul VJ and Fenical W

Chemical defense in tropical green algae, order *Caulerpa*les

Marine Ecology Progress Series 1986, 34:157-169

The secondary metabolites of forty nine species belonging to the order *Caulerpa*les were investigated. The metabolites belonged to the terpenoid group and included caulerpenyne, petiodial, and chlorodesmin. These compounds were toxic to microorganisms, sea urchin larvae, and herbivous fishes. Higher levels of the compounds were found in young growing tips and reproductive structures than in mature tissue.

Meetings Abstracts/Symposium Proceedings

Paul V

Chemical Ecology of *Caulerpa spp.* With an Emphasis on Invasive *Caulerpa taxifolia*

International Caulerpa taxifolia Conference Proceedings 2002

14 *Caulerpa* species have been studied and the majority have the sesquiterpene caulerpenyne as a major metabolite. Most species of *Caulerpa* are consumed by fish. Extracts from several *Caulerpa spp.* containing caulerpenyne did not prevent the fish from feeding. *C. ashmeadii* and *C. bikinensis* produce sesquiterpene aldehydes and are not fed on by fish. *C. taxifolia* is not palatable to fish and has been shown to produce caulerpenyne, oxytoxins, *taxifolia*ls and other terpenes.

Paul VJ

Chemical ecology of *Caulerpa spp.* with an emphasis on invasive *Caulerpa taxifolia*

International Caulerpa taxifolia Conference Proceedings 2002

Many species of the genus *Caulerpa*, including *C. taxifolia*, produce the sesquiterpene caulerpenyne. Caulerpenyne can make up to 2% of the algal dried weight and occurs in higher concentrations in the fronds than in the rhizomes. *C. ashmeadii* and *C. bikinensis* produce sesquiterpene aldehydes. *C. taxifolia*, in addition to caulerpenyne, also produces oxytoxins, *taxifolia*ls, and other terpenes.

Web-based Articles

Rohnert HG

Wound reaction of *Caulerpa spp.* Signals in plankton

Max-Planck-Institut fur chemische Okologie 2003

Caulerpenyne is involved with the chemical defense of *C. taxifolia*. This research showed that during a wound response, caulerpenyne is converted to an esterase which then releases unstable 1,4-bisaldehydes whose functions have not been elucidated. This suggests that not only is caulerpenyne involved with chemical defense, it may also be a precursor of other reactive defensive compounds.

Growth/Photosynthesis/Light Responses

Journal

Martien, MA

Phenology of a deep-water population of *Caulerpa racemosa var. cylindracea* in the northwestern Mediterranean Sea

Botanica Marina 2005, 48:80-83

The growth of *C. racemosa* was measured at a depth of 22 meters off the coast of southeastern France. It was determined that at this depth, the stolon biomass was up to 12 times greater than the frond biomass. This is in contrast to other *Caulerpa spp.* which allocate more biomass to the fronds than the stolons.

Zafar M

Seaweed culture in Bangladesh holds promise

INFOFISH International 2005, 1(3):8-10

Trial cultivations of *Caulerpa racemosa* and *Hypnea spp.*. were attempted in Bangladesh. The culture systems consisted of line, net or suspended rope method. Under cultivation, the growth rate of *Hypnea spp.* was 1.06 cm/day and that of *C. racemosa* was 1 cm/day during October-April. During the monsoon, growth was not observed. Both species grew better under higher salinity than lower (30 ppt vs. below 24 ppt).

Longheed V and Stevenson RJ

Exotic marine macroalga (*Enteromorpha flexuosa*) reaches bloom proportions in a coastal lake of Lake Michigan

Journal of Great Lakes Research 2004, 30:538-544

Enteromorpha flexuosa was discovered in Muskegon Lake in autumn 2003 and by September 2003, it covered from 10 to 80% of the littoral zone. It is speculated that the success of *Enteromorpha* was due to the nutrient enrichments in the areas, increased salinity due to industry and the lack of biocontrol agents.

Raniello R, Lorenti M, Brunet C, and Buia MC

Photosynthetic plasticity of an invasive variety of *Caulerpa racemosa* in a coastal Mediterranean area: light harvesting capacity and seasonal acclimation

Marine Ecology Progress Series 2004, 271:113-120

The photosynthetic plasticity of *Caulerpa racemosa var. occidentalis* growing in a meadow of *Cymodocea nodosus* was studied. The results showed that *C. racemosa* growing in dense or sparse canopy of *C. nodosus* did not exhibit differences in respiration rates suggesting that differences in light regime did not produce detectable physiological stress. When, components of the photosynthetic apparatus were compared, significant differences were apparent. Under a dense canopy of *C. nodosus*, *C. racemosa* produced higher levels of chlorophyll a, chlorophyll b, siphonaxanthin and siphonein than under a sparse canopy. The levels of lutein and antheraxanthin concentrations were higher under the sparse canopy than the dense canopy. During the winter, chlorophyll a levels in *C. racemosa* were higher than during the summer. Chlorophyll b, siphonaxanthin and siphonein levels did not differ between the two seasons.

Thibaut T, Meinesz A, and Coquillard P

Biomass seasonality of *Caulerpa taxifolia* in the mediterranean Sea

Aquatic Botany 2004, 80:291-297

The biomass of *C. taxifolia* in the Mediterranean Sea was measured for a period of one year. Measurements were taken at two depths (5 and 20 meters) and at four sites. Results showed that the biomasses ranged from 55 to 518 gram dry weight/m^2. The highest values were found during the summer and autumn. All sites exhibited similar biomass values except during the summer months when the values were higher. At the 5 meter depth, biomass was from 203 to 518 gram dry weight/m^2. At the 20 meter depth, the biomass ranged from 62 to 466 gram dry weight/m^2.

Piazzi L, Balata D, Ceccherelli G, and Cinelli F

Comparative study of the growth of the two co-occurring introduced green algae *Caulerpa taxifolia* and *Caulerpa racemosa* along the Tuscan coast (Italy, western

Cryptogamie Algologie 2001, 22(4):459-466

The invasiveness of *C. taxifolia* and *C. racemosa* along the Tuscan coast near Livorno, Italy was studied 1998. At the beginning of the study, the area was mapped and then mapped again at the end of the study a year later. It was determined that within this period, the area covered by *C. taxifolia* increased by 67.5% while that of *C. racemosa* increased by 284.8%. The number of individual colonies of *C. taxifolia* increased by 11.4% and that of *C. racemosa* increased by 121.4%. Finally, the lengths and numbers of *C. racemosa* stolon exceeded that of *C. taxifolia*.

Chisholm JRM, Marchioretti M, and Jaubert JM, Marchioretti M, and Jaubert JM

Effect of low water temperature on metabolism and growth of a subtropical strain of *Caulerpa taxifolia* (Chlorophyta)

Marine Ecology Series 2000, 201:189-198

Caulerpa taxifolia tolerance to cold temperatures was determined by exposing the plant to temperatures of 9 to 15^{o}C for 4 to 10 weeks. After 4 weeks at 9 to 11C, chlorosis was apparent on the fronds except for the tips of the pinnules. After an additional 1 to 2 weeks, the alga began to decompose.

Collado-Vides L and Robledo D

Morphology and photosynthesis of *Caulerpa* (Chlorophyta) in relation to growth form

Journal Of Phycology 1999 35:325-330

The morphological and photosynthetic abilities of *Caulerpa spp.* growing on exposed coral reefs and lagoons were studied. These species included the shade-tolerant *C. lanuginosa*, the sun-tolerant *C. paspaloides*, and *C. cupressoides*. Morphologically, all three species were similar with respect to number of stolon branches and number of rhizoid clusters per stolon. However, only the sun-tolerant *C. paspaloides* grew on the reefs. All three species grew in the lagoons in canopies. The shade-tolerant species grew in the understory , while the sun-tolerant *C. paspaloides* grew at the top of the canopy. *C. cupressoides* occupied both reefs and lagoons. *C. cupressoides* photosynthetic rates differed in both niches. Higher rates were exhibited on reefs.

Chisholm JRM and Jaubert JM

Photoautotrophic metabolism of *Caulerpa taxifolia* (Chlorophyta) in the NW

Marine Ecology Series 1997, 153:113-123

The oxygen production and consumption and growth rates were measured for *C. taxifolia* at 10, 15, and 25 meters. These values were similar to the theoretical rates for photoautotrophic organisms. The growth rates at 99 meters were way beyond those of any photoautotrophic values. This suggested that *C. taxifolia* may garner nutrients by heterophylly.

Komasutu T, Meinesz A, Buckles D

Temperature and light responses of alga *Caulerpa taxifolia* introduced in the Mediterranean Sea

Marine Ecology Progress Series 1997, 146:145-153

Cuttings of *Caulerpa taxifolia* were grown under different photoperiods and temperatures ranging from 6 to 34^{o}*C.* The upper lethal temperature was between 31.5 and 32.5^{o}*C.* The lower lethal temperature was between 9 and 10^{o}*C.* The alga did not exhibit and growth between 10 and 12.5^{o}*C.* New stolons and fronds were observed at 15 to 17.5^{o}*C.* As the temperature increased, stolon growth increased. The optimal photoperiod for growth was 14 hours.

Terrados J and Ros JD

The influence of temperature on seasonal variation of *Caulerpa prolifera* (Forsskal) Lamouroux photosynthesis and respiration

Journal of Experimental Marine Biological Ecology 1992, 162:199-212

The photosynthetic and respiration rates of *Caulerpa prolifera* varied throughout the year. Both rates increased linearly with temperatures between 10^{o}C to 30^{o}C or 35^{o}C throughout the year. However, the respiration rates were more susceptible to changes in temperature in February than in May, August or November.

Riechert R and Dawes CJ

Acclimation of the green alga *Caulerpa racemosa var. uvifera* to light

Botanica Marina 1986, 29:533-537

Caulerpa racemosa growing at 1 meter at high light intensity had greater photosynthetic rates than plants grown at 37 meters and those grown at 1 meter under low light intensity. In addition, the *C. racemosa* grown at 1 meter at high light intensity had lower levels of photosynthetic pigments, chloroplasts and less thylakoid surfaces.

Khaleafa AF, Mohsen AF and Shaalan SH

Effect of different light intensities on growth, amino acid, fat and sugar concentrations in *Caulerpa prolifera* (Foerskal) Lamouroux

Hydrobiological Bulletin 1982, 16(2-3):207-212

Caulerpa prolifera was exposed to light intensities between 700 and 3000 lux at 20^{o}*C.* At 20^{o}C, optimal growth occurred at 2500 lux. In addition, at this light intensity, maximum levels of peptides, total soluble sugars and total lipids were measured.

Chen JCW and Jacobs WP

Quantitative study of development of the giant coenocyte *Caulerpa prolifera*

American Journal of Botany 1966, 53(3):413-423

The growth rates and patterns of leaves, rhizomes, and rhizoid clusters of *Caulerpa prolifera* were determined. These organs exhibited a growth rate of 4.4 mm per day. The rhizomes growth rates followed a linear pattern. It was determined that the rhizomes elongated at their tips and that new rhizomes are initiated approximately 0.84 mm from their tips.

Meetings Abstracts/Symposium Proceedings

Johnston CS

Studies on the ecological and primary production of Canary Islands marine algae

Proceedings of the International Seaweed Symposium 1969, 6:213-222

Surveying the Canary Islands with scuba divers, it was determined that the primary alga species was *Cystoseira abiesmarina*. Other species identified were *Cystoseira fimbriata*, *Padina pavonia* and *Jania rubens.* None of these species were found below 15 meters. *Caulerpa prolifera* and *Zostera* were also identified. The population of *C. prolifera* was very low but was discovered as far down as 50 meters.

Report

LaPointe BE and Yentsch CS

Physiology and Ecology of Macroalgal Blooms on Coral Reefs off Southeast Florida

ECOHAB Research Projects (1997 - 2003): Project Summaries

This is a two year study to measure the seasonal patterns of *Codium* and *Caulerpa* species in Florida with respect to such parameters as photosynthetic and respiration rates. The purpose is to determine the feasibility of using herbivores to control macroalgal booms. Methods to employ includes use of underwater digital video to quantify growth patterns and measuring changes in C:N:P in tissue..

De Haro L, Jouglard J, Thomas M, and David JM

First International workshop on *Caulerpa taxifolia*

GIS Posidonie 1994

Workshop summarizing growth, control and regulation of *C. taxifolia*.

Web-based Articles

Hawaiian Reef Algae

University of Hawaii Botany 2004

The University of Hawaii Botany Department website containing a key to identify seven *Caulerpa spp.* including *C. taxifolia* and *C. racemosa*.

Species of Algae: *Caulerpa taxifolia*

IPTEKnet 2004

Caulerpa taxifolia is a green alga that is 10-15 cm in height. It is found in the tidal zone and sub tidal zone. It can grow in sand substrate coral.

Biodiversity, Dynamics and Interaction in Benthic System: Seagrass Ecosystem

Stazione Zoologica Anton Dohrn Activity Report 1997

This research was conducted at the Benthic Ecology Laboratory on the island of Ischia describing the seagrass ecosystem in the Mediterranean. The main emphasis was on *Posidonia oceanica* and *Cymodocea nodosa*.

Nutrients/Nutrient Responses

Journal

Chisholm JR and Moulin P

Stimulation of nitrogen fixation in refractory organic sediments by *Caulerpa taxifolia* (Chlorophyta)

Limnology and Oceanography 2003, 48(2):787-794

The rates of nitrogen fixation by microbes in dead sea grass tissue (*Posidonia oceanica*) colonized with and without *C. taxifolia* were measured using the acetylene reduction method. The results were extremely variable. However, on average, the culture with the colony of *C. taxifolia* had increased rates of Nitrogen fixation by a factor of 28.

Aliya R and Shameel M

Marine natural products (*Siphonocladophyceae*)

Pakistan Journal of Botany 2003, 35:659-669

Five species of *Caulerpa*, including *C. taxifolia* and *C. racemosa*, were analyzed for fatty acid, sterols and diterpene constituents. The authors were able to identify 36 fatty acids and 5 sterols. The most common steriod was chlolesterol. In addition, 2 acyclic straight chain diterpenoids were also identified. The analysis of the data revealed that these 5 species of *Caulerpa* differed in their composition of fatty acids, sterols and diterpene.

Ceccherelli G and Cinelli F

A pilot study of nutrient enriched sediments in a *Cymodocea nodosa* bed invaded by the introduced alga *Caulerpa taxifolia*

Botanica Marina 1999, 42:409-417

Two concentrations of N and P were added to seabeds containing *C. nodosa* and *C. taxifolia*. The pore water was sampled over time and showed that the N concentration was higher in all samples from treated plots versus controls. The P, however, did not show any significant difference from treated and control except for the 2 day sampling time. The contents of N and P in two species were not statistically different between control and nutrient enhanced plants.

Chisholm JRM, Dauga C, Ageron E, Ageron E, Grimont PAD, and Jaubert JM

'Roots' in mixotropic algae.

Nature 1996, 381:382.

Caulerpa taxifolia attaches to substrates via rhizoids. Experiments with 14C-valine demonstrates that this alga takes up nutrients from the substrate and translocates them throughout the fronds and stolon.

Williams SL

Uptake of sediment ammonium and translocation in a marine green macroalga *Caulerpa cupressoides*

Limnology and Oceanography 1984, 29(2):374-379

The rhizoids of *C. cupressoides* ability to take up $15NH_4Cl$ from the interstitial waters suggested that the alga get its nutrients from the sediments rather than from the water column.

Williams SL

Decomposition of the tropical macroalga *Caulerpa cupressoides* (West) *C.* Agardh: Field and laboratory studies

Journal of Experimental Marine Biology and Ecology 1984, 80:109-124

Caulerpa cupressoides decomposition was studied to determine if it was a good source of nutrients for seagrasses. Nitrogen released was primarily in the formed of dissolved organics with only trace amounts of nitrates and nitrites. The C/N ratio increased as the alga decomposition progressed. These two factors suggested that *C. cupressoides* would be a poor source of nutrients for detritivores.

Genetic Analysis

Journal

Meusnier I, Valero M, Olsen JL, and Stam WT

Analysis of rDNA ITS1 indels in *Caulerpa taxifolia* (Chlorophyta) supports a derived, incipient species status for the invasive strain

European Journal of Phycology 2004, 39:83-92

Insertion-deletion Indels (mutations in two or more nucleotides) from 159 published sequences of ITS1 for *C. taxifolia* were compared. Five indelotypes, I_3, I_2, I_{1a}, I_{1b}, I_0, were identified. I_3 was identified as the ancestral type with the complete ITS1 sequence. I_0 contained the most mutations with the loss of 3 inserts. The I_0 indelotype was found in the invasive form in the Mediterranean, California, and southeastern Australian. I{1} was found in Australia and New Caledonia. I_2 was found in the Red Sea and Jakarta.

Yeh WJ and Chen GY

Nuclear rDNA and internal transcribed spacer sequences clarify *Caulerpa racemosa* vars. From other *Caulerpa* species

Aquatic Botany 2004, 80:193-207

The rDNA and internal transcribed spacer sequences of *Caulerpa racemosa var. microphysa*, *C. racemosa var. macrophysa*, *C. racemosa var. peltata*, *C. racemosa var. laetevirens*, *C. serrulata*, *C. webbiana*, and *C. cupressoides* were compared to determine if rDNA and ITS sequences could be used to distinguish *C. racemosa* from other *Caulerpa* spp.. The result showed that the greatest similarities occurred between *C. racemosa var. peltata* and *var. laetevirens*. The least amount of similarities occurred between *C. racemosa* var. *microphysa* and *var. macrophysa*. In addition, similarities between all *C. racemosa* varieties and the other *Caulerpa spp.*. were very low. The results suggest that *C. racemosa var. microphysa* may be a distinct species and that these sequences can be use discriminate between species.

Murphy NE and Schaffelke B

Use of amplified fragment length polymorphism (AFLP) as a new tool to explore the invasive green alga *Caulerpa taxifolia* in Australia

Marine Ecology Progress Series 2003, 246:307-310

An Amplified fragment length polymorphism (AFLP) technique using a 4 primer combination was developed to study the genetic diversity of *C. taxifolia* beds found in Australia and the Mediterranean. AFLP determined that the strain in Moreton Bay which was native was similar to that from the introduced strain in Lake Conjola. With AFLP, the authors were able to show distinctions between the Mediterranean strains and other strains. AFLPs apparently gave better resolution in distinguishing strains than the other molecular techniques.

Fama P, Jousson O, Zaninetti L, Meinesz A, Dini F, Di Giuseppe G, Millars AJK, and Pawlowski J

Genetic polymorphism in *Caulerpa taxifolia* (Ulvophyceae) chloroplast DNA revealed by a PCR-based assay of the invasive Mediterranean strain

Journal of Evolutionary Biology 2002, 15:618-624

The intron of the rubisco large subunit, rbcL (735 bp) is found in several species of *Caulerpa* including *C. okamurae* and *C. racemosa var. macrophysa* but not in *C. brachium* or *C. racemosa var. palate*. 50 aquarium and open-sea *C. taxifolia* specimens were screened for the presence or absence of the intron. It was absence from the invasive Mediterranean strain. The ITS region of ribosomal DNA was also screened in these 50 specimens. The invasive strain had a zoomorphic ITS variant. These genetic polymorphisms can be used to differentiate between stains of *Caulerpa*.

Fama P, Wysor B, Kooistra WHCF, and Zuccarello GC

Molecular Phylogeny of the genus *Caulerpa* (*Caulerpa*les, Chlorophyta) inferred from the chloroplast tufA gene

Journal of Phycology 2002, 38:1040-1050

Comparison of a partial sequence (820 bases) of the chloroplast tufA gene among 46 *Caulerpa* samples representing 18 species was used to develop a phylogenetic tree between these species. This tree differed from that based on morphological features. These results suggested that *C. mexicana*, *C. sertularioides*, *C. taxifolia*, *C. webbiana*, and *C. prolifera* were monophyly. The remaining *Caulerpa* species were para- or polyphyly.

Meusnier I, Valero M, Destombe C, Gode C, Desmarais E, Bonhomme F, Stam WT, and Olsen JL

Polymerase chain reaction-single strand conformation polymorphism analyses of nuclear and chloroplast DNA provide evidence for recombination, multiple introductions and nascent speciation in the *Caulerpa taxifolia* complex

Molecular Ecology 2002, 11:2317-2325

To study the genetic diversity of *C. taxifolia* strains a new genetic marker from the chloroplast DNA, cp 16S rDNA intron-2 was developed. This marker is to complement the ITS rDNA marker. The 16S rDNA intron marker was used to determine the genetic diversity of *C. taxifolia* strains. These data were combined with data from studies with the ITS rDNA marker. The conclusions from these studies determined that there are 2 clades of *C. taxifolia* in Australia. One clade included the invasive population with the inland population in Australia. The other clade included all the offshore-island populations.

Schaffelke B, Murphy N, Uthicke S

Using genetic techniques to investigate the sources of the invasive alga *Caulerpa taxifolia* in three new locations in Australia

Marine Pollution Bulletin 2002, 44:201-210

Sequencing of the internal transcribed spacer (ITS) region of the rDNA from 3 new strands of *C. taxifolia* from Port Hacking, Lake Conjola and Careel Bay New South Wales in Australia was used to determine the origin of these specimens. The results were then compared to published sequences that showed that these 3 strains belonged to distinct clades. The strain in Lake Conjola was similar to that from the Aquarium in Stuttgart. The other two strains were distinct from this Mediterranean strain. The Port Hacking variety however was similar to the tropical native type.

Meusnier I, Olsen JL, Stam WT, Destombe C, Valero M

Phylogenetic analyses of *Caulerpa taxifolia* (Chlorophyta) and of its associated bacterial microflora provide clues to the origin of the Mediterranean introduction

Molecular Ecology 2001, 10:931-946

54 rDNA-ITS sequences from *C. taxifolia* (Mediterranean basin, Western Polynesia, Japan, Australia, Malaysia, the Caribbean and 6 different aquaria) and 16S rDNA sequences from seaweed associated bacterial (4 different hosts from Mediterranean, Tahiti, the Philippines and Australia) were compared to determine the geographical source of the Mediterranean stain of *C. taxifolia*. The results of their analysis identified two geographical groups-- Atlantic-Caribbean and Pacific-Polynesian. The Australian and Mediterranean/aquarium strains always clustered together suggesting that the Mediterranean strain originated from Australia. To support this conclusion, the authors also determined that the microorganisms associated with the Australian and Mediterranean strains were similar. The most commonly *Caulerpa* associated-bacteria are the alpha Proteobacteria.

Wiedenmann J, Baumstark A, Pillen TL, Meinesz A, Vogel W

DNA fingerprints of *Caulerpa taxifolia* provide evidence for the introduction of an aquarium strain into the Mediterranean Sea and its close relationship to an Australian population

Marine Biology 2001, 138:229-234

DNA fingerprinting (southern analysis with Taq I digestion) was used to differential different genotypes of *C. taxifolia*. The authors determined that the fingerprints from strains from aquaria from Stuttgart, Ulm and Enoshima were identical and the Mediterranean strains from Monaco, Krk, and Sicily were identical. This suggested that the Mediterranean strains were released from aquaria.

Fama P, Olsen JL, Sam WT, and Procaccini G

High levels of intra- and inter-individual polymorphorism in the rDNA ITS1 of *Caulerpa racemosa* (Chlorophyta)

European Journal of Phycology 2000, 35:349-356

Caulerpa racemosa ITS sequences from 78 clones representing 11 populations collected from the western Mediterranean, the Canary Islands, Panama and Western Australian were compared. Results showed that all samples collected from the Mediterranean were indistinguishable. High levels of polymorphism existed between the samples from Panama, the Canary Islands and the Mediterranean. Samples from Australia were similar to those from the Mediterranean.

Olsen JL, Valero M, Meusnier I, Boele-Bos S, Boele-Bos S, and Wytze T

Mediterranean *Caulerpa taxifolia* and *C. mexicana* (Chlorophyta) are not cospecific

Journal of Phycology 1998, 34:850-856

To explain the sudden appearance of *C. taxifolia* in Mediterranean in 1984, it was hypothesized that it was a morphological variant of *C. mexicana*. To test this hypothesis, the DNA sequences of the 3' end of the 18S ribosome DNA, ITS1, 5.8S and ITS2 regions were compared. Results showed clearly that these two plants are two distinct species.

Meetings Abstracts/Symposium Proceedings

Olsen J, Meusnier I, Stam WT, and Valero M

Tracing Invasions With Genetic Markers

International Caulerpa taxifolia Conference Proceedings 2002

Two new genetic markers, the chloroplast rDNA 16S intron 2 and intersimple-sequence-repeat fingerprints (ISSRs), were used to group *C. taxifolia*. The results from these analysis suggested that the Mediterranean and California strain are from Brisbane and that the Brisbane strain is from northern Australia. Also, the Mediterranean strain may be from two introductions and the Mediterranean and Australian strains can be grouped into two divergent clades.

Pighini M

Biogeography of *Caulerpa taxifolia* (Chlorophyta) Based on Comparisons of Nuclear rDNA ITS Sequences

The Journal of Eukaryotic Microbiology/19th Annual Meeting of the Society of Protozoologists 1998

Authors studied the ribosomal ITS (internal transcribed spacers) sequences of the Tyrrhenian and Adriatic strains of *C. taxifolia* to try to determine the genetic variations between these two types. There were two ITS fragments; ITS1 which is 104 bp and ITS2 which is 276 bp. The results suggest that significant genomic variations exist between the two populations.

Technical Report

Schaffelke B, Murphy N, Uthicke S

Caulerpa taxifolia in Australia using genetic tools to explore sources of putative introductions

Australian Institute for Marine Science 2002, 44:204-210

Several new colonies of *C. taxifolia* were discovered in New South Wales. Sequencing of the ITS region of the ribosomal DNA was utilized to try to determine the origin of these colonies. The authors also developed an AFLP method to try to determine the origins of these types.

Web-based Articles

Millar A

Caulerpa taxifolia genetics

Botanic Gardens Trust 2003

This described the history of the spread of *Caulerpa* as determined by DNA fingerprinting. It was concluded with DNA fingerprinting that a native species of *C. taxifolia* from Queensland, Australia was sent to Stuttgart, Germany where it developed into a cold tolerant species that was very difficult to control. It was then sent to other aquaria in Europe including the Oceanographic Institute of Monaco. This strain was found in Australia. Rock or sea salt were effective in killing the alga with little damage to sea

Impacts

Journal

Levi F, Boutoute M, and Mayzaud P

Lipid composition of *Symphodus ocellatus* (Perciforme: Labridae) in the north-western Mediterranean: influence of two different biotopes

Marine Biology 2005, 146:805-814

Symphodus ocellatus is a common bottom dwelling fish inhabiting the Mediterranean Sea. The lipid content and fatty acid composition of two populations of *S. ocellatus* were compared. One population inhabited a bed of *Posidonia oceanica* and the other a bed of *Caulerpa taxifolia*. Results showed that the lipid contents in the livers differed between the two populations. The lipid contents in the gonads and eggs, however, were similar. The *S. ocellatus* living in the *C. taxifolia* bed contained 21% less lipid than the biotype inhabiting the *P. oceanica* bed. In addition, the triacylglycerol fatty acid compositions of the two population also differed. It is suggested that in the *C. taxifolia* bed, the growth of this alga reduced the accessibility to the substratum and thus reducing accessibility to the fauna. Therefore, the *S. ocellatus* must then exert more energy, in the form of using fatty acids, to forage for food.

Longepierre S, Robert A, Levi F, and Francour P

How an invasive alga species (*Caulerpa taxifolia*) induces changes in foraging strategies of the benthivorous fish *Mullus surmuletus* in coastal Mediterranean ecosystems

Biodiversity and Conservation 2005, 14:365-376

The foraging behavior of the striped red mullet, *Mullus surmuletus*, was studied in the French Mediterranean. *M. surmuletus* foraged for prey on the sandy bottom. In areas colonized by *C. taxifolia*, the sandy habitats were reduced resulting in the reduction in the abundance and diversity of prey for *M. surmuletus*. To compensate for this, *M. surmuletus* changed its foraging behavior. For example, as the cover of *C. taxifolia* increased, the foraging budget and distanced covered decreased. In addition, the fish also increase the sampling period and swam above the bottom.

Nyberg CD and Wallentinus I

Can species traits be used to predict marine macroalgal introductions?

Biological Invasions 2005, 7:265-279

Interval arithmetic was used to quantify species traits in a attempt to determine whether introduced species will be successful in establishing in a new environment. Three major categories, dispersal, establishment, and ecological impact, were scored. These major areas were broken down further into subcategories. In this method, each alga was given a score of between 0 (least risk) and 1 (greatest risk) for each category. By applying this method, the authored determined that all exotic species had higher scores than the native species. The highest ranking species and thus most invasive were *Codium fragile spp. tomentosoides*, *Caulerpa taxifolia*, *Undaria pinnatifida*, *Asparagopsis armata* and *Grateloupia doryphora*.

Balata D, Piazzi L, and Cinelli F

A comparison among assemblages in areas invaded by *Caulerpa taxifolia* and *C. racemosa* on a subtidal Mediterranean rocky bottom

Marine Ecology 2004, 25(1):1-13

The macroalgal assemblages in the Mediterranean invaded by *C. taxifolia* and *C. racemosa* were compared. It was determined that the erect and turf species were similar for both species but the amount of encrusting species was greater in the *C. taxifolia* invasion. In addition, *C. racemosa* was more invasive than *C. taxifolia*, and thus replaced more of the original species.

Levi R and Francour

Behavioural response of *Mullus surmuletus* to habitat modification by the invasive macroalga *Caulerpa taxifolia*

Journal of Fish Biology 2004, 64:55-64

The feeding behaviour of the fish, *Mullus surmuletus*, in Alpes-Maritimes, France was altered in environments that have been invaded by *Caulerpa taxifolia*. *M. surmuletus* did not forage in areas that were colonized by *C. taxifolia* but were found to forage over bare sand and endemic macroalgae.

Piazzi L, Ceccherelli G, and Cinelli F

Treat to macroalgal diversity: Effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean

Marine Ecology Progress Series 2001, 210:149-159

The invasion of 2 macroalgal community by *Caulerpa racemosa* in the Mediterranean was studied. Stolons of *C. racemosa* elongated at faster rates (2 cm per day) than the native macroalgal species and within 6 months completely covered the two sites. This resulted in the decrease in the species diversity in these regions. During the periods when *C. racemosa* naturally died back, the native macroalgal populations did not recover.

Davis AR, Roberts DE, Cummins SP

Rapid invasion of a sponge-dominated deep-reef by *Caulerpa scalpelliformis* (Chlorophyta) in Botany Bay, New South Wales

Australian Journal of Ecology 1997, 22:146-150

Within four months of invading a deep-reef habitat in Botany Bay, Australia, *Caulerpa scalpelliformis*, covered 56% of the substratum. At the same period, the native sessile invertebrates had decreased from 48% cover to 23% cover. Twelve months after the initial invasion, *C. scalpelliformis* was found 300 meters from its original location and also on non-continuous reef.

Boudouresque CF, Lemee R, Mari X, Meinesz A

The invasive alga *Caulerpa taxifolia* is not a suitable diet for the sea urchin *Paracentrotus lividus*

Aquatic Botany 1996, 53:245-250

The sea urchin, *Paracentrotus lividus*, normally feeds on algae such as *Rissoella verruculosa*, *Padina pavonia*, and *Cystoseira amentacea*. When *C. taxifolia* was included in the diet of *P. lividus* with either of the other species, *P. lividus* preferentially fed on the other species. When the sea urchins did feed on *C. taxifolia*, they lost weight and began to lose their spines.

Newspaper/Magazine

Carlton JT

Introduced Species in US Coastal Waters

Pew Oceans Commission 2001

This booklet describes the bioinvasions of plants and animals into US coastal waters. Methods include by ship ballast, sea plants and aquarium trade. One of the introduced species was *C. taxifolia* which was probably introduced by the aquarium trade. The introduced species could be control with a variety of means such as mechanical control, chemical control, biocontrol and public education on how not to spread the invading species.

Simons M

A Delicate Seaweed Is Now a Monster of the Deep

New York Times 1997

This article summarizes what is known about *C. taxifolia* in the Mediterranean. It is believed to have a tropical origin and a hybrid of this stain was created in a German zoo that can easily adapt to different environments where it easily out competed other plants and even animals. The *C. taxifolia* was released into the sea probably by the Oceanographic Museum of Monaco when they cleaned out their tanks. Mechanical removal was used mainly to try to control the plant without much success. A snail from the Caribbean was discovered that attacked the plant. However, at of this writing, the French government had not allowed for its release.

Web-based Articles

Coral Smothering "Green Tide" Seaweed Spreading on Florida Reefs

Science Daily

Caulerpa brachypus has been found in the reefs in Florida's Palm Beach County and in Ft. Pierce. *C. brachypus* growth kills the reefs and decimates the fauna and flora in the area. It is hypothesized that the rampant growth of this alga is the result of the nutrient-enriched environment caused by the pollutants in the area.

Travizi A and Zavodnik N

Phenology of *Caulerpa taxifolia* and temporal dynamics of its epibiontic neiofauna in the port of Malinska (Croatia, northern Adriatic Sea)

Scientia Marina 2003, 67:145-157

The epibiontic meiofauna in the *C. taxifolia* strand at the Malinska Port (Kirk Island, northern Adriatic Sea) was studied. 14 meiofaunal taxa were identified including Copepoda (58%) and Nematoda (25%). The study showed that during the summer-autumn months, *C. taxifolia* frond lengths increased accompanied by increases in meiofaunal abundance.

An example: The *Caulerpa taxifolia*

Biological Pollution 2000

Since *C. taxifolia* introduction into the Mediterranean, the biodiversity in the infected areas have been reduced. Before the invasion of this alga, *Cymodocea nodosa* was prevalent. After the invasion, the plant has disappeared. As of this writing, effective measures of controlling this alga have not been found.

"Killer algae" could be endangering reefs

Science News Online

The growth of *Caulerpa* in the nutrient-enriched water in the reefs off the shores of Riviera and Palm Beach, Florida leads to a cascading effect. The smaller reef organisms die off, followed by the departure of the small fishes and then the departure of the large fishes.

Turkey to attend terrorist moss summit

Turkish Daily News (TDN) 1998

Caulerpa racemosa was found in the Turkish's province of Mersin, Seven Islands of Gokova, and the Bodrum Coast. The ecosystems of infected areas were aversely impacted.

Regulatory and Policy

Journal

Anderson LWJ

A review of aquatic weed biology and management research conducted by the United States Department of Agriculture--Agricultural Research Service

Pest Management Science 2003, 58:801-813

This paper summarizes the research of the past 4-5 years by USDA-ARS in weed biology, ecology, physiology and management strategies (herbicides, biological control, and natural products,).

Meetings Abstracts/Symposium Proceedings

International *Caulerpa taxifolia* Conference Proceedings

International Caulerpa taxifolia Conference Proceedings International Caulerpa taxifolia Conference Proceedings 2002

This CD contains the complete proceedings of the International *Caulerpa taxifolia* Conference held in San Diego, CA in 2002.

Anderson LWJ

Caulerpa taxifolia in the United States: rapid response and eradication program

Proceedings of the 11th EWRS International Symposium on Aquatic Weeds 2002

The Southern California *Caulerpa* Action Team was formed within 4 weeks after the first discovery of *C. taxifolia* in Southern California. This rapid response was possible because of several factors including: quick identification of the plant; immediate communication with governmental agencies; consensus to eradicate the alga; crew and funds in place; and cooperation among all responsible parties.

Thibaut T and Meinesz A

Management Successes and Failures in the Mediterranean

International Caulerpa taxifolia Conference Proceedings 2002

The uncontrollable spread of *C. taxifolia* in the Mediterranean was due to the lack of eradication policies by the governments involved (France, Spain, Italy, Croatia, and Tunisia). These governmental policies for *C. taxifolia* control involved only mapping and public outreach programs. The widespread invasion of *C. taxifolia* precluded its eradication. The use of biocontrol agents may be effective in its control.

Thibaut T and Meinesz A

Management successes and failures in the Mediterranean

International Caulerpa taxifolia Conference Proceedings 2002

Management of *C. taxifolia* in the Mediterranean since its introduction has been a failure and at this point in time cannot be eradicated. Since it cannot be eradicated, the continual spread of the alga must be controlled.

Williams S

The Role of Science in Management of the *Caulerpa taxifolia* Invasion in Southern California

International Caulerpa taxifolia Conference Proceedings 2002

In California, Assembly Bill 1241 mandates " that management of marine life should be based on science and take an ecosystem approach" which is achieved by scientific peer review. This approach must be implemented for controlling the invasion of *C. taxifolia* in California.

Newsletter

Caulerpa taxifolia is wanted in the Albanian seashore

United Nations Development Programme 2004

A United Nations project was funded to raise the public awareness of *C. taxifolia* in Albania and to determine if this alga has indeed spread to this country's shoreline. To accomplish the first goal, leaflets were distributed outlining the problems and consequences of *C. taxifolia*. For the second goal, 8 specialists will dive into the waters of Albania to visually document the presence or absence of the alga.

Caulerpa taxifolia

Coastal Currents - The newsletter of the Sydney Coastal Councils Group 2002, 29

The Sydney Coastal Councils Group (SCCG) of Australia was established to "promote coordination and cooperation between member councils on environmental issues relating to the sustainable management of the urban coastal environment". Due to the actions of the SCCG, the government has provided $445,000 from the Natural Heritage Trust to the New South Wales Fisheries and CSIRO for the control and eradication of *C. taxifolia*.

Fakes T

Caulerpa Ban in California

Seascape (Instant Ocean) 2001, 18:1

Assembly bill 1134 was introduced in the California legislature to ban the possession of *Caulerpa spp.* The sale and importation of *C. taxifolia* were already illegal. The banning of the all *Caulerpa spp.* stems from the notion that aquarists and enforcement staff cannot differentiate between *C. taxifolia* from other *Caulerpa spp.*

Interdepartmental action plan on the alga *Caulerpa taxifolia*

Ministere de l'Ecologie et du Development Durable (France) 1999

The *C. taxifolia* steering committee in France decided that there are 3 main areas of importance in the control of *C. taxifolia*. They are its nature and origin, socio-economic impacts, and affects on the ecosystems. Visual surveys by professionals and amateurs will be conducted to record the spread of the alga. The public will be educated about the problems and consequences of the alga. Control methods will be implemented to stop the spread of *C. taxifolia*. This is the plan for the next 5 years.

Newspaper/Magazine

The latest on the spread of the *Caulerpa taxifolia* algae in the Mediterranean

Medwaves News Bulletin 1997, 34:11-13

C. taxifolia was found on the French coast in 1984. It was then only 1 sq meter. By 1990, it spread to 2 sites covering 30 hectares. In 1994, 1500 hectares were covered and by 1996 3000 hectares of the alga covered the sea floor. To control the spread of the alga, two provisions of Article 13 of the Barcelona Convention's Protocol on Specially Protected Areas were adopted (1996). These basically stated that all appropriate measures must be taken to prevent the introduction of non-indigenous species into the environment and that all measures must be implemented to eradicate alien species that have

Report

Draft NSW Control Plan for the noxious marine weed *Caulerpa taxifolia*

NSW Fisheries 2003, 20 pp

This reports describes a prevent plan developed for the control of *C. taxifolia* in New South Wales, Australia. It includes control, management, education and community involvement, treatment, monitoring and research on *Caulerpa*.

Agua Hedionda Lagoon User Representatives (SCCAT)

To Facilitate the Alga Hedionda Lagoon *Caulerpa Taxifolia* Eradication Program

Interim Management Plan

This management plan was drawn up for the successful implementation of the Rapid Response and Eradication Program for the control of the invasion of *C. taxifolia* developed by the Southern California *Caulerpa* Action Team (SCCAT). The main focus of the plan was to provide a framework for cooperation between all parties, including recreational users and eradication personnel, to prevent the spread of the alga beyond the

lagoon.

GAO

Invasive Species: State and other Nonfederal Perspectives on Challenges to Managing the Problem

GAO Perspectives on Invasive Species 2002, 12(6):112-117

Report sent to The Honorable James Inhofe and The Honorable Michael *C.* Crapo, both of the Committee on Environment and Public Works. The reports summaries a 2003 survey results to describe 4 problem areas in controlling invasive species. One is gaps or problems with federal legislation. Two concerns barriers in trying to managing invasive species. Three concerns requirement of leadership structure. Four involves the plus and minus of having invasive species legislation.

Williams SL

Supplemental Testimony on The Seaweed Genus *Caulerpa* 2001

This is the report that SL Williams presented to the California Assembly Appropriations Committee on the impact *Caulerpa* may have in California if not controlled. She described the introduction of *C. taxifolia* into Southern California and its rapid spread and the necessity of a means to differentiate it from other *Caulerpa* species so that its spread can be prevented.

Technical Report

Keppner S and Caplen RT

A Prevention Program for the Mediterranean Strain of *Caulerpa taxifolia*

Aquatic Nuisance Species Task Force 1999, Draft 21pp

This draft report describes a comprehensive plan to prevent the introduction, establishment and dispersal of the invasive Mediterranean strain of *C. taxifolia* in U.S. waters.

Web-based Articles

Caulerpa taxifolia

California State Water Resources Control Board (CSWRCB) 2003

California Environmental Protection Agency web site on *Caulerpa taxifolia*. Assembly bill 1334 outlawed the sale, possession, and transport of all *Caulerpa* species that look similar to *Caulerpa taxifolia*. This site contain links to public documents on eradication efforts.

Stime J

Caulerpa taxifolia, The Killer Algae

Aquarium Design 2002

This article appeared in Aquarium Design's Website (specializes in marine algae and living coral reef aquaria) in reference to California's Assembly Bill #1334 which " Makes it unlawful to sell, possess, import, transport, transfer, release alive in the state, or give away without consideration the saltwater algae of the genus *Caulerpa*." The author felt that the bill unfairly burdened his industry.

Henley J

Fifteen years ago it was a small patch of seaweed, now it threatens to ruin the Mediterranean coast

Guardian Unlimited 1999exocetus

Since its introduction into the Mediterranean in 1984, *C. taxifolia* spread has been rampant to a point that scientists believe that it cannot be eradicated. The article states that groups of environmentalists, fishermen and amateur divers filed a compliant with the French government for its inaction on the control of *C. taxifolia*. There are several theories on why the French government has not added. One is that the French did not want a diplomatic incident with Monaco (Monaco introduced the alga into the Mediterranean). The other theory is that *C. taxifolia* has no natural enemies and is not harmful to humans. Therefore, money was not spend on its control.

History

Book

Meinesz A

Killer algae

Killer algae 1999, 378 pp

"Killer algae" is book on *C. taxifolia* including a description of it's history with its first introduction into the Mediterranean in the 80's and the lack of action by European governments to stem the spread of the alga before it was beyond control. It talked about the impact of *C. taxifolia* on the ecology of any regions it invaded with particular emphasis on the effects of the biodiversity of the floral. It also included efforts to control the alga including the use of biocontrol agents such as the sea slug.

Journal

Miller KA

California's non-native seaweeds

Fremontia 2004, 32(1):10-15

There are 669 species of red, brown, and green seaweeds in California listed in the Marine Algae of California. To determine which of these species were introduced, scientists must rely upon history of collection data and species distribution. Currently, 12 non-native seaweed species have been identified off the California coast. These include *Caulerpa taxifolia*, *Sargassum muticum*, *Undaria pinnatifida*, and *Caulacanthus ustulatus*.

Meetings Abstracts/Symposium Proceedings

Millar A

The introduction of *Caulerpa taxifolia* in New South Wales, Australia

International Caulerpa taxifolia Conference Proceedings 2002

Caulerpa taxifolia is native in eastern Australia and at Lord Howe Island in New South Wales. In April 2000, it was discovered in Port Hacking. It then spread to Lake Conjola, Careel Bay, Pittwater, and Lake Burrill. Genetic analysis suggested that the spreads were the results of two separate introductions.

Newsletter

Woodfield R

Noxious seaweed found in southern California coastal waters

National Marine Fisheries Service 2003

Caulerpa taxifolia was found in Carlsbad, CA in June 2000. Immediately after its discovery, an eradication program was implemented. The *C. taxifolia* was covered with a tarp and herbicides were injected under the tarp. The treatments were successful.

Newspaper/Magazine

Zamora AR

Caulerpa taxifolia

Ecologia La Insignia 2002

This was an article from a newspaper/magazine in Nicaragua about *C. taxifolia* in the Mediterranean. It explains that it is originally from the Caribbean and it spreads like the plaque. It is resistant to cold and can grow centimeter a day. It is toxic and can live out of the water for a week.

Report

Yip M

Essay about *Caulerpa taxifolia*

Marine Biology 1 2002, 9 pp

This describes the history of *C. taxifolia* introduction into the Mediterranean, its biology, spread , and means of control including mechanical and with biocontrol agents.

Web-based Articles

Caulerpa spp....

Florida Department of Environmental Protection (FDEP) 2003

Web site devoted to the general description of *Caulerpa spp.*

Australian Museum Fish Site

Australian Museum 2003

This sites contains questions and answers about *Caulerpa taxifolia* from readers.

Madl P and Yip M

Literature Review on the Aquarium Strain of *Caulerpa taxifolia*

This review outlines the history of *Caulerpa* introduction, dispersal, and methods of controls. It contains an extensive bibliography on *Caulerpa*.

Caulerpa taxifolia - the "killer alga"

Forschung - Entwicklung - Zukunft 2002

C. taxifolia arrived first in Monaco in 1984. It then rapidly spread from France, to Spain, to Italy, and then to Croatia. Where the alga spreads, it displaces the native species such as the native seagrass *Posidonia oceanica*. It can survive out of water for several days and can regenerate from a small fragment and grow up to 80 cm in length. *C. taxifolia* prefers to grow in soil and avoids smooth hard surfaces.

Makowa J

Caulerpa taxifolia

Monterey Bay National Marine Sanctuary Fact Sheet

Caulerpa taxifolia is a green alga growing from 5-65 cm in length. It is found in the Caribbean Sea and the Indian Ocean. A hybrid form is found in the Mediterranean Sea. The alga can survive out of water for 10 days. The alga prefers tropical climates. However, the hybrid can survive from 5 to 10°*C.* Many different methods have been employed to control this alga. Methods include removal by divers, use of poisons, boiling, and use of biocontrol agents.

Escoubeyrou K

File of Alga Tueuse: After Ten Years of Polemic, Science Takes Again the Top

Exocetus 1999

This article summarizes the history of *C. taxifolia* in the Mediterranean. DNA analysis determined that the infestation of the Mediterranean was from the Oceanographic Institute of Monaco. Several methods have been tried to try to control it. Black plastic sheets were used to cover the alga to prevent photosynthesis, copper based algaecides have been applied and biocontrol with several species of slugs (*Elysia subornata* and *Oxynoe azuropunctata*) were all attempted.

Burkhardt S

Caulerpa Taxifolia - the green killer of the Mediterranean?

Palstek Online 1998

This article summarized the history of *C. taxifolia* in the Mediterranean. It had a tropical origin and was brought to the Wilhelma zoo in Stuttgart Germany who then distributed the plant to other institutes. One was the Institute of Monaco which then discarded the plant into the Mediterranean Sea where it rapidly propagated and out competed other plants such as the native *Posidonia* grass.

Raloff J

Rogue Algae: The Mediterranean floor is carpeted with a shaggy, aggressive invader

Science News Online 1998

The *C. taxifolia* found in the Mediterranean is a more aggressive form than that found in its native habitat, the tropics and subtropics. It can grow up to 30 inches in length, survive out of water for up to 10 days, propagate in cold temperatures (50^{o}F) and reproduce from a single fragment. Some scientists believe that this Mediterranean form is a hybrid species or even a completely new species. To control the spread of the alga, mechanical approaches such as manual removal have been unsuccessful. Another approach is the use of biocontrol agents. Two Caribbean sea slugs, the partially shelled *Oxynoe azuropunctata* and the shell-less *Elysia subornata*, hatch on *C. taxifolia* and feed on it. Apparently, the slugs ingest the toxic caulerpenyne and then utilize the toxic to make themselves unappetizing to predators. However, a problem with the sea slug is that the temperatures in the Mediterranean may be too cold for their survival.